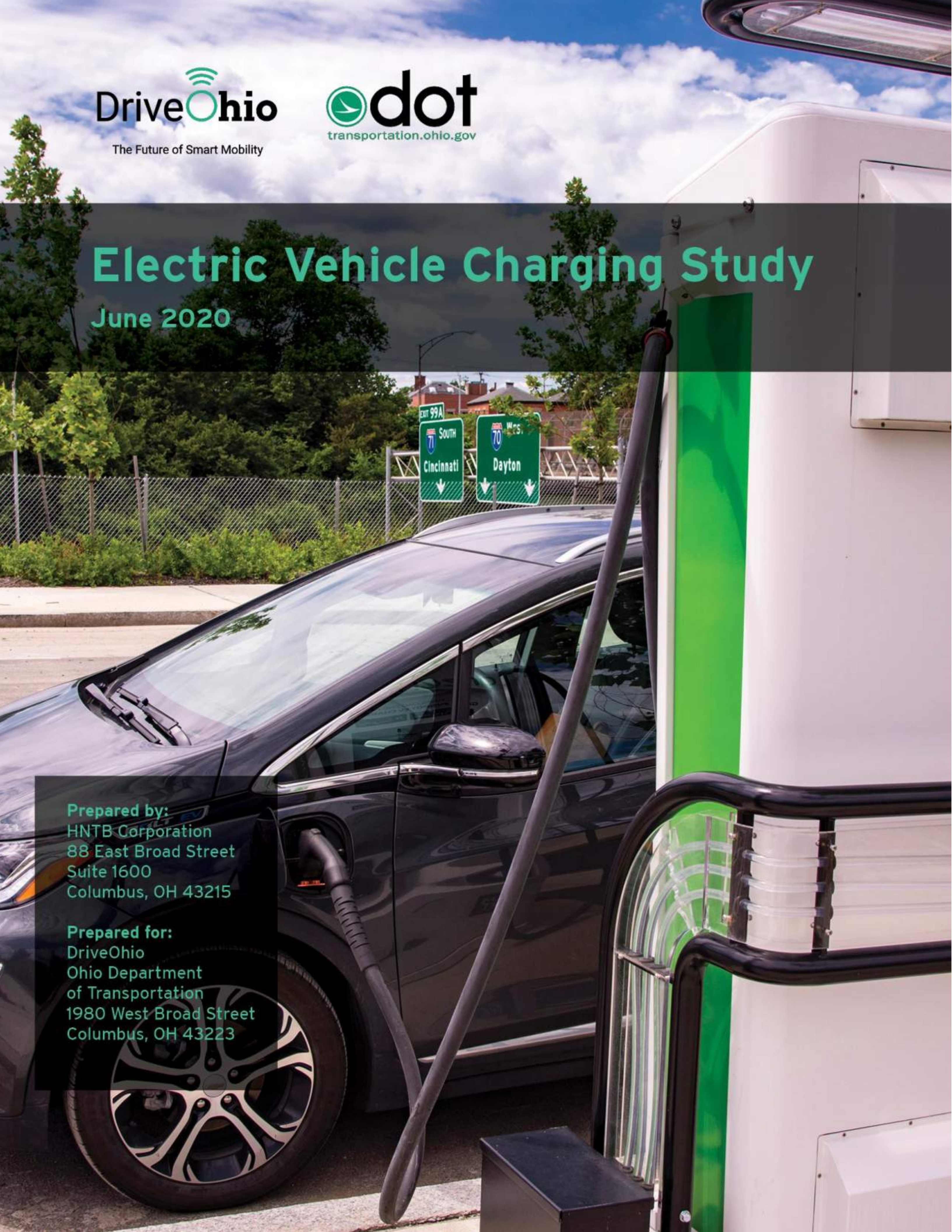

DriveOhio

The Future of Smart Mobility

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Electric Vehicle Charging Study

June 2020

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Cover Photograph

By Bruce Hull of the FRA-70-14.56 (Project 2G) ODOT roadway project in coordination with which the City of Columbus, through a competitive bid, hired GreenSpot to install a DCFC on Fulton Street immediately off I-70/I-71 and adjacent to the Columbus Downtown High School property between Fourth Street and Fifth Street. Funding support for the electric vehicle DCFC was provided by AEP Ohio and Paul G. Allen Family Foundation.

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List of Abbreviations

AADT	Annual Average Daily Traffic
AC	Alternating Current
AEP	American Electric Power
AFDC	Alternative Fuels Data Center
AMP	American Municipal Power
BEV	Battery Electric Vehicle
BMV	Bureau of Motor Vehicles
CCS	Combined Charging System
CHAdeMO	CHArge de MOve
CMAQ	Congestion Mitigation and Air Quality
DC	Direct Current
DCFC	Direct Current Fast Charger
DMTF	Diesel Mitigation Trust Fund
ODNR	Ohio Department of Natural Resources
DP&L	Dayton Power & Light
EA	Electrify America
EPA	Environmental Protection Agency
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAST	Fixing America's Surface Transportation
FE	First Energy
FHWA	Federal Highway Administration
GIS	Geographic Information System
ICE	Internal Combustion Engine
L2	Level 2
LEED	Leadership in Energy and Environmental Design
MP	Mile Post
MPO	Metropolitan Planning Organization
MSRP	Manufacturer Suggested Retail Price
MUD	Multi-Unit Dwelling
NOACA	Northern Ohio Area Coordinating Agency
ODAS	Ohio Department of Administrative Services
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
ODPS	Ohio Department of Public Safety
OEC	Ohio’s Electric Cooperatives
OEM	Original Equipment Manufacturer
OTIC	Ohio Turnpike Infrastructure Commission
PHEV	Plug-In Hybrid Electric Vehicle
PUCO	Public Utilities Commission of Ohio
RFID	Radio-Frequency Identification
SAE	Society of Automotive Engineers
SR	State Route
SUV	Sport Utility Vehicle
TIMS	Transportation Information Mapping System
US	United States
USDOT	United States Department of Transportation
VMT	Vehicle Miles Traveled
VW	Volkswagen
WSDOT	Washington State Department of Transportation
ZEV	Zero Emission Vehicle

Executive Summary

The purpose of this report is to assess needs for electric vehicle (EV) charging, primarily along Ohio's highway corridors. Corridor charging requires relatively high-power Direct Current Fast Charging (DCFC) stations that can rapidly deliver significant added range to EVs at locations that are easily and quickly accessed by motorists. This report identifies DCFC gaps in Interstate, U.S. Highway and State Route corridors and identifies options to fill them. Most of these gaps should and will need to be filled by private commercial site hosts but can be supplemented by installing charging facilities at ODOT rest stops and Ohio Turnpike Service Plazas.

In addition, this report identifies charging needs that facilitate long distance travel and Ohio tourism by ensuring that EV motorists can conveniently recharge their vehicles while they are visiting their destination using Level 2 chargers.

A final objective is to assist state agencies in establishing EV charging to gain direct experience and insight in this field and demonstrate support for this enabler of future mobility. **Figure ES-1** summarizes these three charging goals and the process of analyzing and recommending locations.

Charging Location Recommendations

Using the process shown in **Figure ES-1**, priority charging locations displayed in **Figure ES-2** and summarized in **Table ES-1** were identified. These include:

- DCFC:
  - Twenty-four public charging locations along interstates (one of the gaps does not have a recommended location due to lack of power service – there's an existing DCFC location 1.3 miles from interstate), U.S. Highways and State Route corridors to provide EV charging opportunities at least every 50 miles.
  - Ten public charging locations at Ohio Turnpike service plazas to cover gaps across their facility.
- Level 2:
  - Nineteen public Level 2 charging locations to allow visitors to travel directly to and from attractions and charge their cars while they visit the attractions (including 11 state parks).
  - Seventeen public Level 2 charging locations at ODOT (13 across Ohio), ODPS (3 in Franklin County), and OTIC (Berea headquarters) facilities to assist with public and agency awareness and understanding of the EV ecosystem.

Figure ES-1: Process for Identifying Public Charging

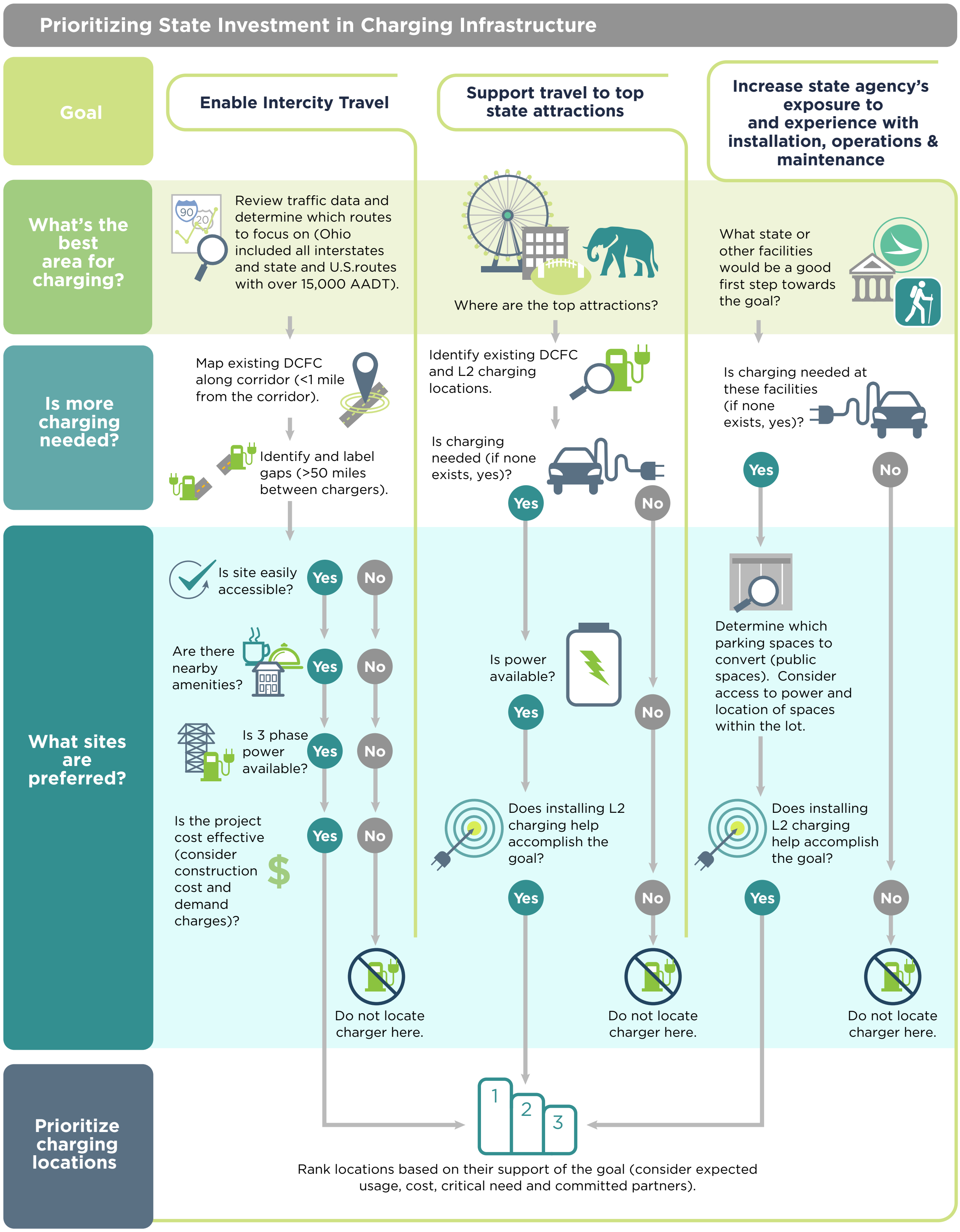


Figure ES-2: Recommendations for Direct Current Fast Charging and Level 2 Charging

Table ES-1: Recommendations Summary

Charger/Location Type	Original Potential Locations	Locations Without Sufficient Power	Remaining Locations	Locations Eligible for VW Funds	Recomm'd Sites	Number of Chargers	Number of Charger Ports
Level 2: Attractions	8	-	-	8	8	16	64
Level 2: ODNR State Parks	11	-	-	5	11	22	88
Level 2: ODPS Locations	3	-	-	3	3	3	6
Level 2: OTIC Office	1	-	-	1	1	1	2
Level 2: ODOT District Offices	13	-	-	6	13	13	26
Level 2: Total	**36**	**0**	**0**	**23**	**36**	**55**	**186**
DCFC: ODOT Rest Areas	11	8	3	1	16	32	32[a]
DCFC: Private Sites (IR)	29	2	27	4			
DCFC: Private Sites (US/SR)	8	0	8	1	7	14	14[a]
DCFC: OTIC Service Plazas	10	0	10	10	10	20	20[a]
DCFC: Total	**58**	**10**	**48**	**16**	**33**	**66**	**66[a]**
Totals	**94**	**10**	**48**	**39**	**69**	**121**	**252**

[a] *Dual-port DCFC includes 1 CHAdeMO port and 1 SAE CCS port to ensure that all BEVs can connect. One car can charge at a time.*

Cost Estimate

Table ES-2 summarizes, the estimated cost of installing chargers at all the recommended locations ranges from $2.3 million ($2.0 million plus $0.3 million) to $4.4 million ($3.6 million plus $0.8 million). Approximately 50% of these costs are within counties eligible for VW funding support through the Ohio EPA, potentially bringing the overall charger and installation costs down to between $1.1 million and $2.0 million.

Table ES-2: Electric Vehicle Charger Cost Estimate Summary

	DCFC (50 kW)	Level 2
No. of proposed sites	33	36
No. of dual-port chargers	66[a]	55[b]
Cost per charger	$25,000-$35,000	$2,605-$6,190
Make-ready work cost per site	$10,000-$40,000	$4,000-$12,000
Total charger & installation cost	$1,980,000-$3,630,000	$287,275-$772,450
Annual O&M costs per charger	$1,400-$2,000	$1,000
Sites eligible for VW funding	16 of 33	23 of 36

[a] *Dual-port DCFC includes 1 CHAdeMO port and 1 SAE CCS port to ensure that all BEVs can connect. One car can charge at a time.*

[b] *All Level 2 charging stations will allow 2 vehicles to charge at one time and will meet the J1772 standard. Recommend 1 dual-port charger per ODOT District Office and Central Office (13 chargers), 1 dual-port charger at each OPDS facility (3 chargers), 1 dual-port charger at OTIC HQ (1 charger), 2 dual port chargers at each state park (22 chargers), and 2 dual-port chargers at private attractions (16 chargers).*

Next Steps

To deliver the recommendations in this report and continue progress towards supporting interstate travel, routes with high AADT, and tourism in Ohio, DriveOhio can:

- Socialize this study with other state agencies, MPOs, utilities and other key stakeholders.
- Conduct outreach to highest priority sites, identify site hosts interested in applying for funding and assist with funding applications.
- Establish a point of contact at each investor owned utility and Ohio's Electric Cooperatives (OEC) and facilitate more detailed conversations between these organizations and the site hosts to ensure the cost of providing power and the rates are not prohibitive and the process can move forward efficiently.
- Develop more detailed cost models and schedules based on ownership decisions.
- Facilitate efforts noted in **Table ES-3** to help Ohio agencies target the most impactful EV readiness activities. The state can further develop this framework to support their constituents.

Table ES-3: Framework for Roles in Supporting Electric Vehicle Adoption

	State	MPO/Regional	County/City
Adoption	• Maintain a list of available EVs on the market (ODPS/Ohio BMV). • Provide latest trends on EV adoption by zip code, city and county to local and regional agencies (ODOT). • Add (ODAS) and publicize to Ohio agencies EV vehicle models that are on the states universal term contract list. • Consider offering EV purchase incentives. • Evaluate state fleet and duty cycles to determine which vehicles may be appropriate for conversion. • Ensure state vehicles have telematics capable of reporting state of charge and other key indicators.	• Publicize to member agencies EV vehicle models that are on the states universal term contract list. • Educate members on needed local policies and encourage adoption. • Educate elected officials and staff on fleet electrification. • Provide forums to consider electrification of government fleets and strategies to incentivize electrification of private fleets.	• Set local fleet electrification goals. • Analyze opportunities to add EVs to local government and other fleets. • Consider, then clarify/adopt EV parking, signage and other regulations. • Ensure vehicles have telematics capable of reporting state of charge and other key indicators.

	State	MPO/Regional	County/City
Charging	• Plan EV corridor charging: gap identification, power supply analyses, priority locations for private sites. • Identify top destination targets for charging. • Develop state-owned sites for corridor DCFC. • Maintain and publicize to Ohio agencies EV chargers that are on the states universal term contract list. • Facilitate (PUCO) utility EV charging programs and adopt EV-related policies and goals. • Develop template for local EV charging planning. • Update state building code for parking garages to facilitate minimum % of "make ready" wiring.	• Identify gaps in regional DCFC charging network, based on shared mobility services and fleets. • Help identify private or government site hosts to fill DCFC gaps. • Identify additional L2 locations based on traffic flows and site characteristics. • Facilitate project partnerships with utilities, charger providers and installers to develop facilities. • Consider establishing EV charging incentives.	• Develop community based EV charging plan addressing multi-unit dwelling, workplaces, public and fleet charging. • Identify priority locations (government, private); set goals for development. • Enact local policies such as "right to charge," "make ready" building codes for new builds and renovations, charging facilities in rights of way, others.

1. Introduction

To evaluate the cost, complexity and appropriateness of installing electric vehicle charging stations to support tourism and intercity travel to and within Ohio, ODOT asked the HNTB team to determine what the state could do in the near term to best support Ohio's needs. The team began by benchmarking other leading states, listening to Ohio stakeholders with experience in the electric vehicle space and meeting with vendors. In parallel, data was gathered on existing state assets, traffic volumes and patterns, utility coverage and the state's existing EV charging infrastructure. Using insights from the conversations with other states and stakeholders, a process was developed to prioritize where the state could best support charging infrastructure deployment.

Corridor charging is a critical component needed to overcome the single greatest market barrier to consumer EV adoption – the lack of adequate charging facilities. This report focuses on recommendations for public DCFC along Interstates, State Routes and U.S. Routes. It also addresses some public Level 2 charging support for top attractions and at other state facilities.

2. Market Conditions and Projections

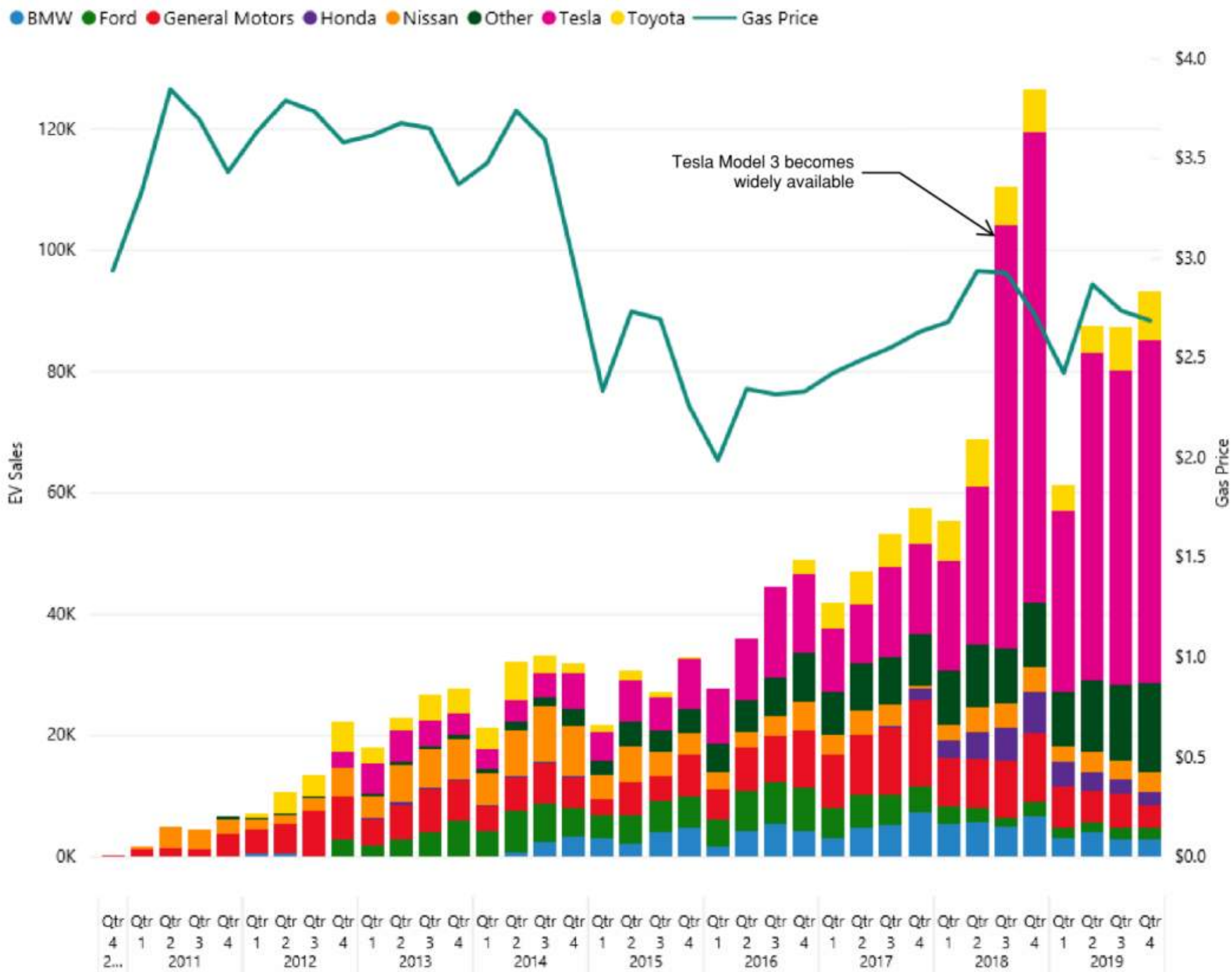
2.1. Recent History

The current electric vehicle era began in 2011 with the introduction of two models by legacy manufacturers, Nissan's Leaf and Chevrolet's Volt, plus two models from start-up, Tesla. The Leaf and Tesla models are battery electric vehicles (BEVs), operating on an electric motor and battery charged by an external plug. The Volt is a plug-in hybrid electric vehicle (PHEV) with a smaller battery pack charged externally but supplemented by an internal combustion engine (ICE) that takes over when the battery is depleted. Other automakers also began offering EV models soon after but relatively few models were available outside of California and a few other states with Zero Emission Vehicle (ZEV) requirements (see **Figure 1**).

The EV market grew more quickly than had the market for hybrid electric vehicles (HEVs) approximately a decade earlier, especially in states with greater consumer choice. **Figure 2** shows EV market share rankings for states with the top five national rankings, followed by Ohio and its adjacent states, for comparison. Availability of mid-market priced BEVs with over 200 miles of range accelerated growth in 2017 and 2018. General Motors began selling the Bolt in late 2016. Tesla's Model 3 began limited production in mid-2017, then accelerated in 2018 to fulfill over 450,000 global pre-orders and has represented over 80% of US BEV (or 53% US PEV) sales in 2018.

By 2018, EVs comprised 1.96% of total annual new vehicle sales. Today, 22 different original equipment makers (OEMs), or automakers, offer a combined total of 42 EV models, including 16 BEVs and 30 PHEVs. Twenty-two of these 42 total models are currently available in Ohio. Consumers interested in other models must order them through out of state dealer relationships. See **Appendix A** for complete list of EVs available.

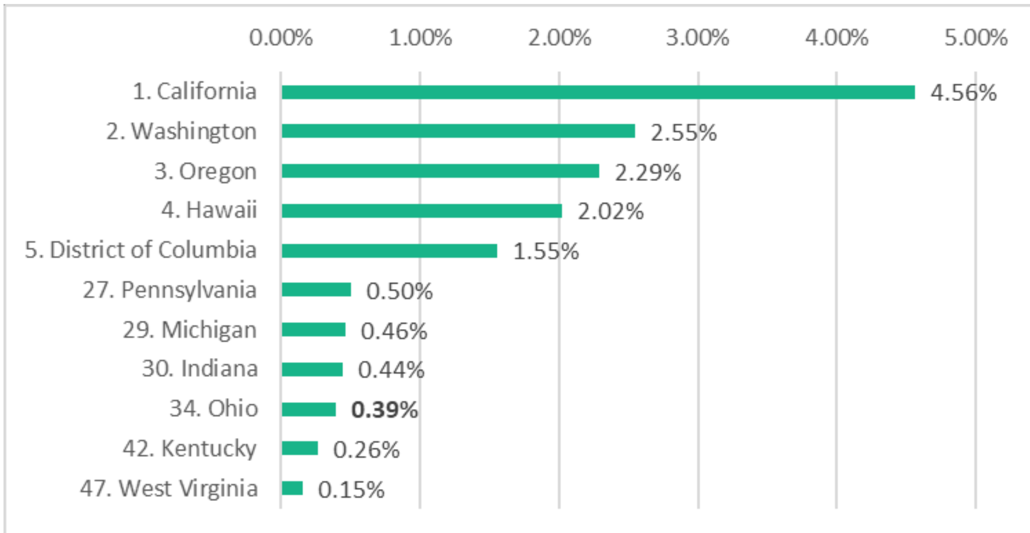
Figure 1: National Electric Vehicle Sales by Manufacturer with Historic Average Gas Prices, 2010-2019



Source: Atlas EV Hub

The highest volumes of EV sales continue to be in California, followed by other west coast and north eastern states. This has resulted from several factors, including state ZEV policies that have incentivized EV manufacturers to offer a wider choice of mid-priced models and early investments in EV charging facilities at public sites, workplaces and multi-unit dwellings by utilities.

Figure 2: Electric Vehicle Market Share Ranking by State

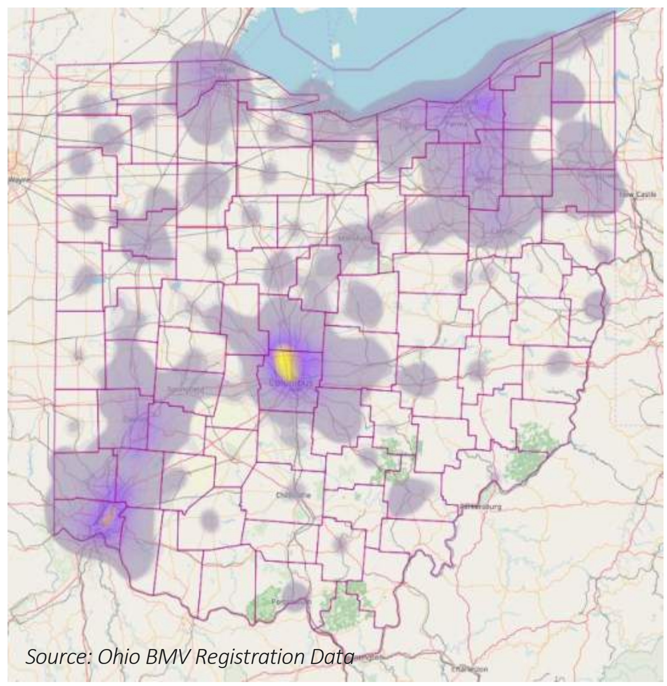


Source: Data from *https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/*

2.2. Electric Vehicle Adoption in Ohio

Figure 3 show the concentration of EVs registered in Ohio. Logically, the highest concentrations of EVs are in the largest metropolitan areas of Cleveland, Columbus and Cincinnati – followed by Akron, Dayton, Toledo and Youngstown. Among these, the greatest acceleration has occurred in the Columbus region. This is due primarily to major consumer education campaigns through Smart Columbus and assisted by some rebates for government fleet purchases. Growth in other metro areas have also been assisted by "grassroots" education campaigns.

Over 40% of plug-in vehicles registered in Ohio are Tesla vehicles (see **Table 1**), all of which are fully battery electric (BEV). Thus, about 75% of the BEVs registered in Ohio are Teslas. Ohio has seen steady growth in electric vehicle sales and registrations. Consistent with national trends, Ohio EV sales have accelerated with the introduction of mid-market priced BEVs with battery pack ranges of over 200 miles.



Source: Ohio BMV Registration Data

Figure 3: Ohio Concentration of Plug-In Vehicles

Table 1: Top Plug-In Models Registered in Ohio in 2019

Make	Model	Type	% of Registered EVs
Tesla	Model S	BEV	12%
	Model X	BEV	4%
	Model 3	BEV	27%
Tesla Sub-Total			**43%**
Chevrolet	Volt	PHEV	17%
	Bolt	BEV	3%
Chevrolet Sub-Total			**20%**
Ford	Fusion Energi	PHEV	5%
	C-MAX Energi	PHEV	4%
Ford Sub-Total			**9%**
Nissan	Leaf	BEV	**7%**
Other	various	mix	**21%**
Total			**100%**

Source: Ohio BMV data

Table 2 summarizes the year over year growth of EVs on a county, state, and U.S. level between 2016 and 2018.

Table 2: Electric Vehicle Sales (Battery and Plug-In Hybrid Models) and Example County Registrations

Year	Franklin County [a]	Ohio Market EV Sales [b]	U.S. Market EV Sales [b]
2016	Registered EVs: 606	• 1,630 EVs (38.3% growth)	• National EV sales rose 28.4% to 145,570
2017	Registered EVs: 1,448	• 2,091 EVs • (28.2% Growth)	• National EV sales rose 29.1% to 187,985 • EV market share increased 33.3% from 0.9% to 1.2%
2018	Registered EVs: 2,948	• 4,456 EVs (113% Growth) • 14,081 total EVs registered	• National EV sales rose 74.54% to 328,118 • EV market share increased 63.3% from 1.2% to 1.96%.

Sources:

a. *Ohio Bureau of Motor Vehicles; Motorist Registration Data by Year; Franklin County, Ohio*

b. *Alliance of Automobile Manufacturers (2019). Advanced Technology Vehicle Sales Dashboard. Data compiled by the Alliance of Automobile Manufacturers using information provided by IHS Markit (2011–2018) and Hedges & Co. (2019). Data last updated 8/20/2019. Retrieved [10/22/19] from https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/.*

2.3. Electric Vehicle Charging Technology Overview

Electric vehicle chargers and methods used to charge EVs are fundamentally unlike refueling a conventional gasoline or diesel vehicle. Unlike petroleum, electricity is supplied into most homes and businesses, so EVs can be charged at any location with access to electricity. Conventional internal combustion engine (ICE) vehicles visit gas stations when they are nearing empty. Most EVs are "topped off" every day. See **Appendix B** for more details.

2.3.1. Charging at Home

According to the U.S. Department of Energy, "most plug-in electric vehicle drivers do more than 80% of their charging at home" (https://www.energy.gov/eere/electricvehicles/charging-home). In many cases, no special equipment is needed for home charging besides a cord set that comes standard with any EV and is plugged into a 110/120V outlet (i.e. Level 1). Depending on routine daily driving, consumers may need a home charging unit to provide power at an amperage comparable to an electric dryer (i.e. Level 2). These units typically cost less than $500, plus any costs needed to provide 240V power to the equipment.

2.3.2. Levels 1 and 2

EV chargers are categorized into three basic types corresponding generally to levels or rates of charge. Levels 1 (L1) indicates power available from a 110/120V outlet carried by a 15 to 20-amp circuit. Level 2 (L2) refers to power delivered by a 240V outlet and carried by a 30 to 80-amp circuit. Level 1 can dispense at a rate of about 4 kW per hour while Level 2 can range from 6.6 kW up to 19.2 kW per hour. Both Level 1 and Level 2 types use the same standard plug, SAE J1772 that fits all EVs. Many Level 2 chargers are available with a dual-port option that allows two vehicles to charge at the same time.

Some Level 2 charging units are considered "dumb" appliances, which are designed only to deliver a charge when plugged into a vehicle. Others include various "smart" features that enable them to communicate, collect data, accept payments, and be subject to remote control. Sites hosting multiple chargers can install "smart" interface equipment to control multiple dumb chargers at the site.

2.3.3. Direct Current Fast Charging

Direct Current Fast Charging (DCFC) equipment delivers power using direct current rather than alternating current. This allows much higher charging rates compared to Level 1 and Level 2 chargers, delivering 25 kWh to 500 kWh per hour (i.e. power levels of 25-500 kW) depending on equipment. Since the introduction of BEVs, public DCFC stations deliver 50 kW using either a SAE Combined Charging System (also known as a CCS or J1772 Combo) or CHAdeMO connector. Many DCFCs allow one vehicle to charge at a time but are referred to as dual-port because they have one CCS and one CHAdeMO connector. Tesla Supercharger stations provide a 90 kW – 250 kW power level and use a special connector that does not attach to other BEVs. Teslas come with an adaptor to use other connector types. Except for the BMW i3 REx and Mitsubishi Outlander, PHEVs don't have DCFC ports because they have smaller batteries and are designed to switch over to gasoline for long trips.

2.3.4. Mobile Charging Units

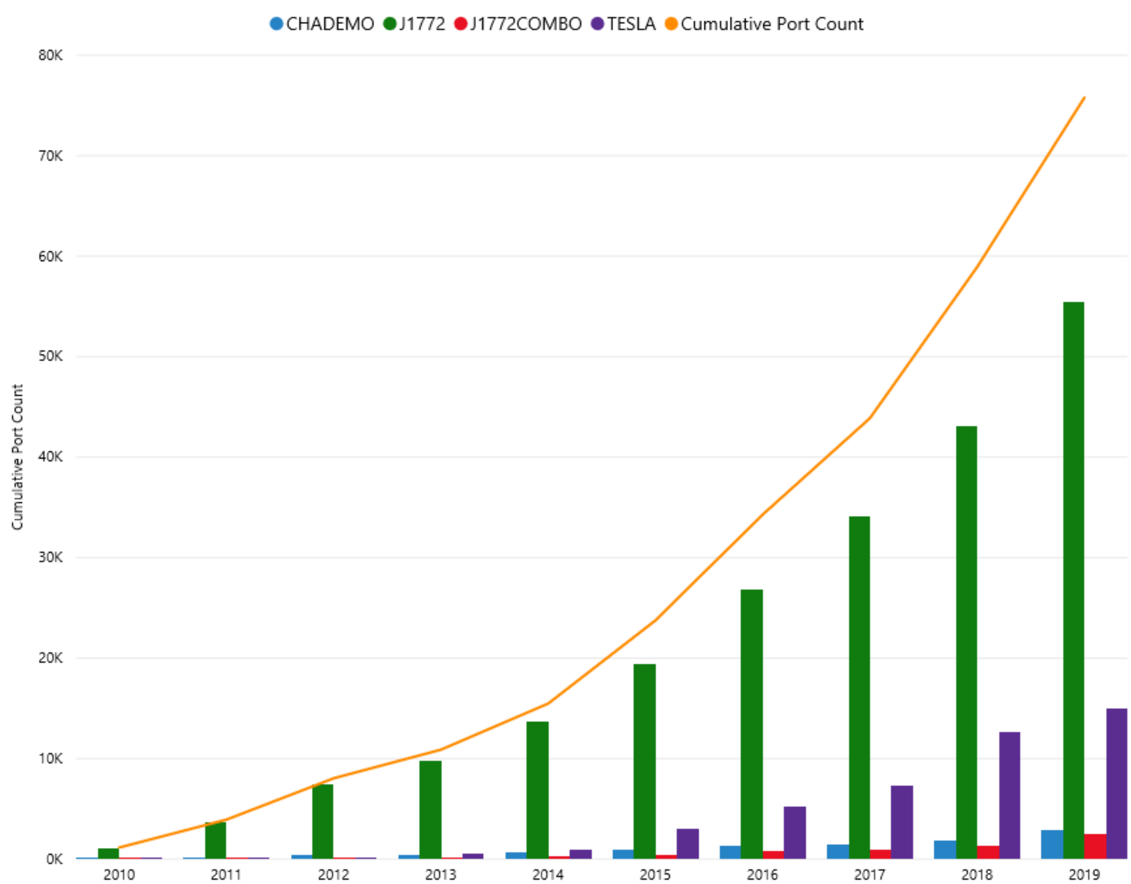
For emergency situations and to help alleviate the anxiety caused by vehicle battery range among EV drivers, companies have introduced mobile charging trucks with on-board generators or large storage batteries. Starting in

2011, AAA introduced a pilot program in select metro areas deploying mobile charging trucks to get stranded EVs charged up enough to get moving. The program was suspended in 2019 after "fairly low" demand, even in EV-saturated California markets, and was not seen as a viable business option to continue. With the network of charging stations currently available, AAA would rather tow an EV to the nearest charging station rather than charge on the spot.

2.3.5. Installation Growth and Future Projections

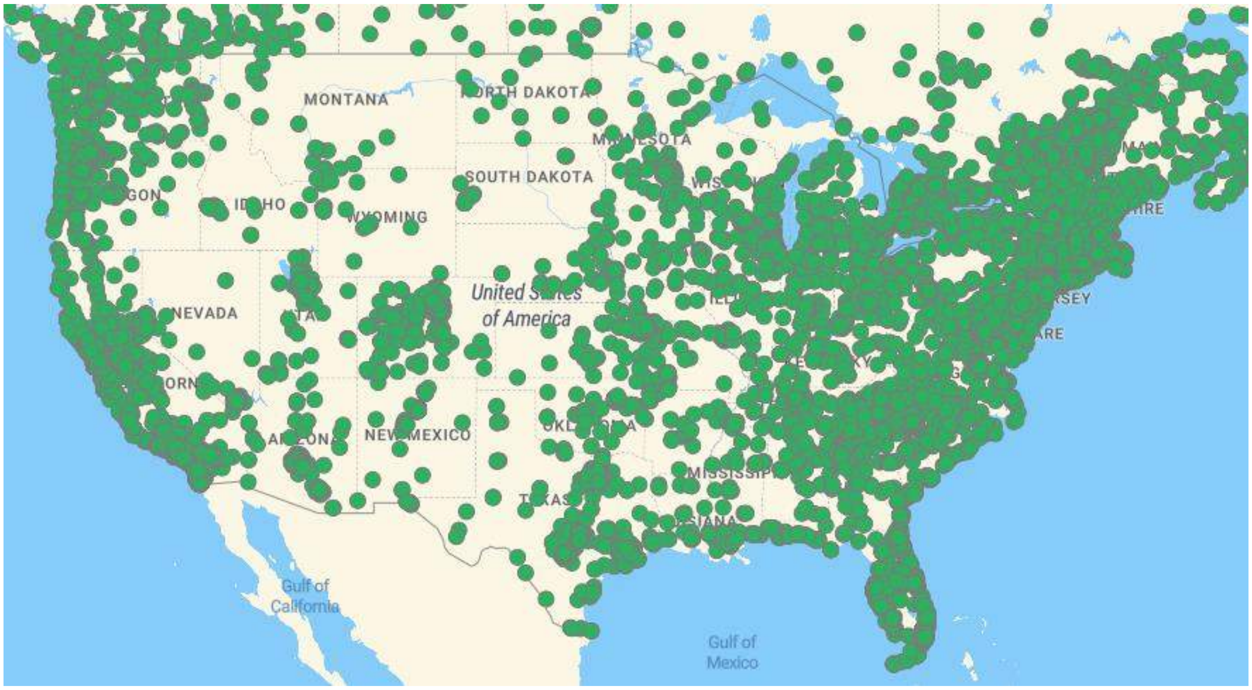
The first Level 2 and DCFC installations began to occur about 10 years ago. **Figure 4** shows the national rates of growth for chargers (includes both Level 2, DCFC, and Tesla chargers). **Figure 5** shows concentrations of Level 2 and **Figure 6** shows concentrations of DCFC.

Figure 4: Cumulative National Charging Infrastructure Growth, 2010-2019



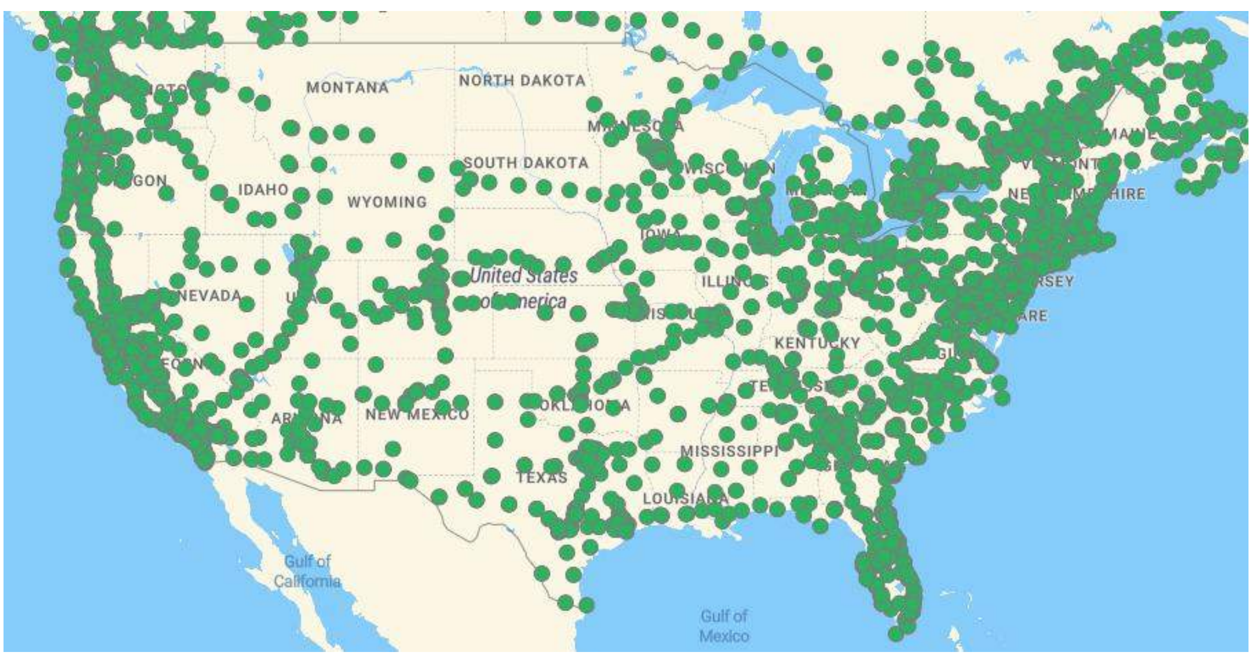
Source: Atlas EV Hub

Figure 5: Existing National Level 2 Charging Infrastructure



Source: Alternative Fuels Data Center, May 2020

Figure 6: Existing National Fast Charging Infrastructure (Including Tesla)



Source: Alternative Fuels Data Center, May 2020

Public DCFC stations will change significantly over the next several years. Growth of pickup trucks and SUVs will disproportionately require more charging than older EV types (lower miles per kWh models). This will become significant after 2022. Electric Class 8 trucks are expected to reach market post 2022. These changes will place more emphasis on the need for higher power DCFCs that require more electrical infrastructure.

The industry has been capable of producing higher power chargers and does so for heavy-duty EV fleets. The limiting factor is capacity of today's EVs to accept higher charging rates. As EV battery technology evolves and is incorporated into new BEVs sold, EVs will be able to accept faster charge rates. The standard for DCFC will likely jump, first to 150 kW then to 350 kW and possibly eventually higher. VW's charging network subsidiary, Electrify America, enables charging at rates up to 350 kW today but provide the option of lower rates.

2.4. Charging Infrastructure in Ohio

As of April 2020, Ohio has 442 Level 2 charging locations with a total of 996 charging ports, and 96 DCFC locations (~480V AC Power) with 286 charging stations. Over half of the DCFC chargers are proprietary to Tesla. Of the remaining DCFCs in the state, only a few are located along travel corridors outside of metro areas according to the US Department of Energy Alternative Fuel Data Center. **Table 3** summarizes the breakdown of DCFCs around the state of Ohio by charging network.

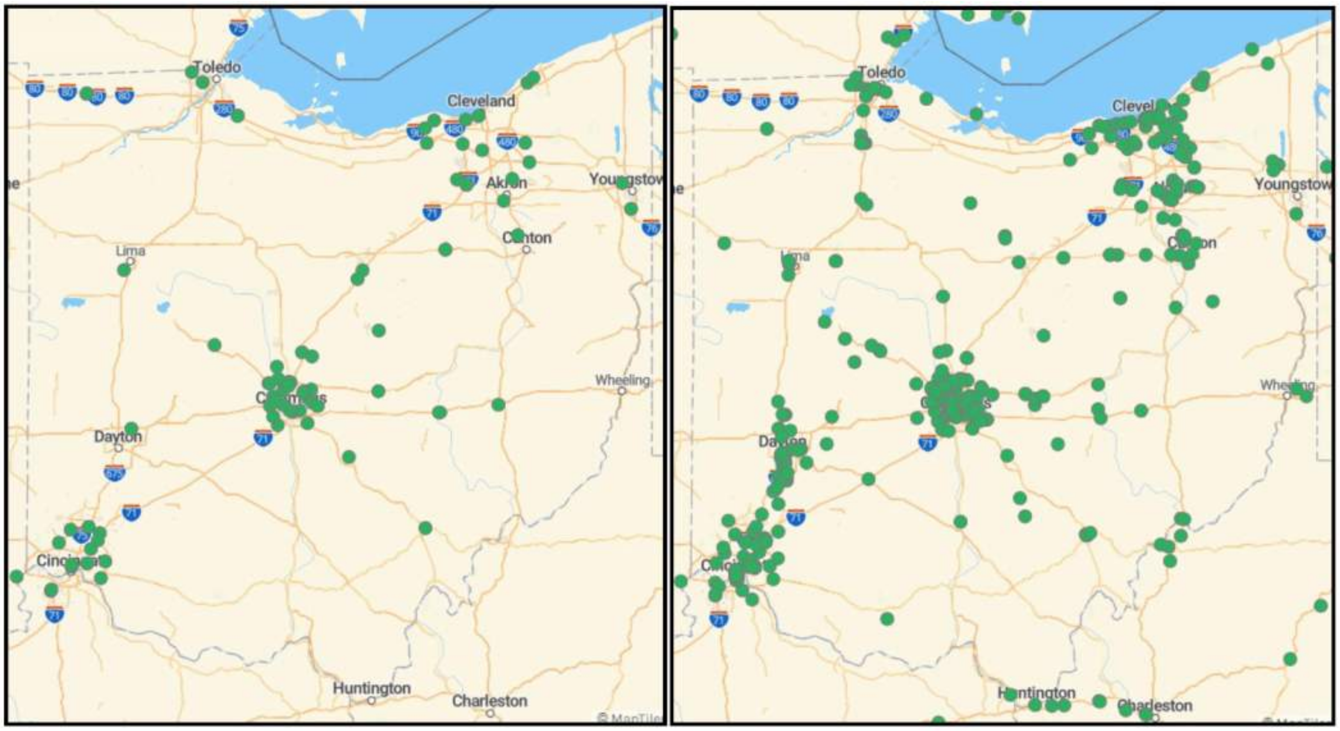
Table 3: Breakdown of Direct Current Fast Charging Networks in Ohio (April 2020)

	DCFC Locations and Number of Chargers			
Charging Networks	**DCFC Locations**	**DCFC Stations***	**% of Locations**	**% of Stations**
Tesla	17	150	18%	53%
ChargePoint	30	38	31%	13%
Electrify America	12	61	12%	21%
EVgo	23	23	24%	8%
Non-Networked	14	14	15%	5%
Total	96	286	100%	100%

* *In this instance, 'stations' represent the number of vehicles that can charge at one time at the given location*
Source: Alternative Fuels Data Center, https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC

Figure 7 shows the distribution of existing DC fast chargers (excluding Tesla Superchargers) and Level 2 chargers in Ohio.

Figure 7: Existing Public Electric Vehicle Charging Infrastructure in Ohio



DC Fast Chargers ***Level 2 Chargers***

Source: Alternative Fuels Data Center, https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC (accessed May 2020)

As detailed later in this report, Ohio will need additional charging infrastructure, particularly an increased number of DC Fast Chargers to facilitate current and future intercity EV transportation in the state. The number and distribution of Level 2 chargers focused around the metro areas do not provide practical solutions for EV drivers on travel corridors due to the long dwell times required to charge.

2.5. Electric Vehicle Market Growth Factors and Projections

2.5.1. Industry Commitments

The US Department of Energy and multiple independent market reports conclude that the automotive industry is committed to electrified mobility. This is evidenced by numerous manufacturers including Ford, GM, Chrysler and Nissan having committed to each bringing 10 or more EV models to market in the 2020s. These manufacturers have also announced billions in investment in US and foreign EV manufacturing facilities.

New vehicles announced will have even longer ranges, surpassing 300 and even 400 miles on a charge. Companies will also offer larger vehicles. Ford's partnership with Rivian to bring a fully electric F-150 to market by 2021 is one example of this with ranges rumored to be greater than 400 miles per charge.

Consumer choices will expand across the full range of models. As time progresses through the middle part of the 2020's, continuing declines in battery costs and technology improvements will cause growth in models at lower as well as mid-market price points as EVs overall (including pickups and more SUVs) reach initial purchase price parity with ICE vehicles. In addition to vehicles themselves, many automakers have also acquired stakes in companies that specialize in charging and battery technology and production. **Table 4** and **Table 5** provide more specifics on these points.

Table 4 summarizes key findings from an August 2019 report titled *EV Market Status – Update: Manufacturer Commitments to Future Electric Mobility in the U.S. and Worldwide,* produced by M.J. Bradley & Associates.

Table 4: Electric Vehicle Market Status

Finding	Description
Large Increase in EV models by 2022	Between 2019 and 2022, the number of battery electric (BEV) and plug-in hybrid (PHEV) models available to U.S. consumers will increase from 51 to 80. The range of vehicle types available will also increase to include sport utility vehicles (SUV), cross-overs, and pick-up trucks.
Battery Range Increasing; Prices Falling	The cost of battery packs has fallen dramatically, from approximately $1,000/kilowatt-hour (kWh) in 2010 to approximately $176/kWh in 2018. Most analysts project that battery pack prices will continue to fall, reaching $100/kWh around 2025 and $62-72/kWh by 2030. Auto manufacturers have endorsed these projections.
EV Price Parity with Conventional Vehicles	There is general industry consensus that EVs will reach price parity with ICE vehicles (based on total cost of ownership without considering any tax incentives) when battery pack prices fall below $100/kWh. While some industry experts believe this could happen as early as 2021, most believe it will happen around 2025.
5 Models Under $30K by 2021	By 2021 there will be at least five EV models available for under $30,000 (MSRP) with a range of up to 250 miles. There will be even more models with a net cost of under $30,000 when current federal, state, and local incentives are factored in.

Source: Electric Vehicle Market Status – Update: Manufacturer Commitments to Future Electric Mobility in the U.S. and Worldwide, Lead Authors: Dana Lowell and Alissa, M.J. Bradley & Associates for the Environmental Defense Fund (EDF), www.mjbradley.com/sites/default/files/ElectricVehicleMarketStatusUpdate08142019.pdf

Table 5 summarizes the EV commitments and investments currently stated by major domestic automotive manufacturers.

Table 5: Major Manufacturer Electric Vehicle Commitments

Manufacturer	Commitment
Ford: $11B in EV Investments; 16 EVs by 2022	Ford has stated a goal of having sixteen fully electric vehicles in their portfolio by 2022 and has announced plans to convert two of its North American plants to build plug-in models. As part of its $11 billion EV investment, Ford is investing $500 million in Rivian to develop an all-new, next-generation BEV for Ford's portfolio.
General Motors: $300M in MI plant; multiple EV models	GM announced plans to invest $300 million in its plant in Orion Township, Michigan to manufacture a Chevrolet vehicle based on the battery-powered Bolt. General Motors (GM) has also positioned Cadillac to be its lead electric vehicle brand going forward, highlighting the BEV3 platform and declaring that "our commitment to an all-electric, zero emissions future is unwavering."

Manufacturer	Commitment
Fiat Chrysler: $4.5B in 5 MI Plants; 30 EV Models by 2022	Fiat Chrysler will invest $4.5 billion in five of its existing Michigan plants in addition to building a new assembly plant in Detroit, which will both continue to produce existing ICE models as well as enable electrification of new Jeep models; Fiat-Chrysler has committed to producing more than 30 electrified models by 2022, 10 of which will be PHEV Jeeps and four will be all EV Jeeps.
Rivian: Amazon orders 100,000 electric delivery vans	Amazon will purchase 100,000 delivery vans for an estimated $4 billion that are expected to be on the road by 2024. Amazon has already invested $700 million in the Michigan-based electric startup.
Worldwide: $135B in EV Investments by 2030	In total, carmakers worldwide will spend more than $135 billion through 2030 developing new electric models. In addition to expanding their portfolios to include a greater range of electric and electrified models, manufacturers like Nissan and Volvo have acquired stakes in companies that specialize in charging and battery technology while Audi, Ford, Mercedes-Benz, and Volkswagen have announced they will each invest billions of dollars in electrification strategies.

Source: Electric Vehicle Market Status – Update: Manufacturer Commitments to Future Electric Mobility in the U.S. and Worldwide, Lead Authors: Dana Lowell and Alissa, M.J. Bradley & Associates for the Environmental Defense Fund (EDF), www.mjbradley.com/sites/default/files/ElectricVehicleMarketStatusUpdate08142019.pdf.

2.5.2. Summary of Medium to Long-Term Market Growth Factors:

Analysts are universally confident in their predictions of EV growth for several reasons. **Appendix C** includes details about the main factors impacting growth, but in summary they include the following:

- **Global Market:** Today, global market forces, especially in Europe and Asia, have emerged as powerful EV market drivers. To compete in these large markets, U.S. manufacturers must offer attractive EV options.
- **Battery Cost Declines:** Battery costs will continue to decline due to the normal research and development process due to billions of investment dollars and accelerating economies of scale.
- **Shared Mobility:** Due to high utilization and low operating costs, electrification is a great fit for new and legacy shared mobility services. The growth trend advancing these services will accelerate the drive toward electrification.
- **Commercial EVs:** Large scale deployment of fully electric over the road trucks is still years away. However, EVs have achieved or soon will reach life-cycle cost parity for certain applications, including last-mile delivery and other niche use cases. Similar to what is happening with light duty vehicles, a growing number of options for mid and heavy-duty electric trucks will help drive cost parity with ICE trucks.

Table 6 summarizes a report produced by the Edison Electric Institute (EEI) and the Institute for Electric Innovation (IEI), titled: *Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030.*

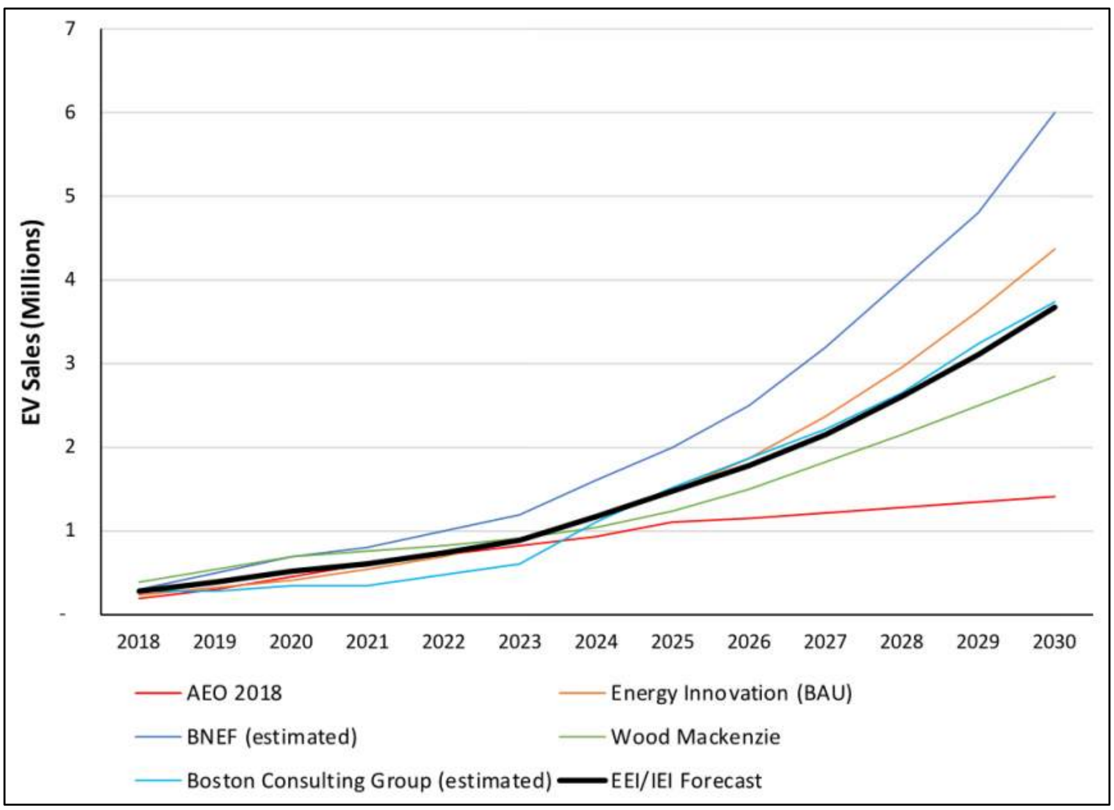
Table 6: Electric Vehicle Sales Forecasts

Forecast	Description
18.7 Million EVs on US Roads by 2030	The stock of EVs on the road is projected to reach 18.7 million in 2030, up from slightly more than 1 million at the end of 2018. This is about 7 percent of the 259 million vehicles (cars and light trucks) expected to be on U.S. roads in 2030.
1 Million More US EVs by 2021	It took 8 years to sell 1 million EVs. EEI/IEI project the next 1 million EVs will be on the road in less than 3 years—by early 2021.
2030 EVs More than 20% US Annual Sales	Annual sales of EVs will exceed 3.5 million vehicles in 2030, reaching more than 20 percent of annual vehicle sales in 2030. Compared to the EEI/IEE 2017 forecast, EV sales are estimated to be 1.4 million in 2025 versus 1.2 million.

Source: Plug-in Electric Vehicles Sales Forecast Through 2030 and the Charging Infrastructure Required. Edison Electric Institute and Institute for Electric Innovation. November 2018. *www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20EV%20Forecast%20Report_Nov2018.pdf.*

Figure 8 illustrates U.S. market sales projects for EVs from 2018 to 2030, summarizing six different market projection models as detailed below.

Figure 8: Annual Electric Vehicle Sales Forecast



Sources:

a. *U.S. Energy Information Administration (EIA) – Annual Energy Outlook 2018 Reference Case (February 2018):* https://www.eia.gov/outlooks/aeo/

[b] *Bloomberg New Energy Finance (BNEF) – Electric Vehicle Outlook 2018 (May 2018):* https://about.bnef.com/electric-vehicle-outlook/#toc-download

[c] *Boston Consulting Group (BCG) – The Electric Car Tipping Point (November 2017):* https://www.bcg.com/en-us/publications/2018/electric-car-tipping-point.aspx

[d] *Energy Innovation – Energy Policy Simulator 1.4.1:* https://us.energypolicy.solutions/scenarios/home

[e] *Wood Mackenzie – The Electric Vehicle Outlook Data (August 2018):* https://www.woodmac.com/nslp/electric-vehicles-guide/

[f] *Edison Electric Institute and Institute for Electric Innovation. Plug-in Electric Vehicles Sales Forecast Through 2030 and the Charging Infrastructure Required. November 2018.* http://www.ehcar.net/library/rapport/rapport233.pdf

2.5.3. Short-Term Uncertainty in U.S. Electric Vehicle Market

Significant EV market growth in the United States is certain; however, in the short term, certain factors may cause slower growth or even temporary market declines.

First among these is uncertainty of federal EV tax credits. In 2008 federal policymakers established tax credits for battery electric and plug-in hybrid electric vehicles. Each automaker was allocated 200,000 credits. Upon reaching this total, the credits were designed to ramp down and end. Tesla was the first OEM to reach this cap. GM has now surpassed it and Nissan is close.

Table 7 lists the percentage toward reaching the cap per automaker. It is uncertain whether Congress will extend the credits for automakers that have or will soon reached their cap. If credits are not extended, some analysts expect a decline in sales over the next two or three years until new models hit the market and additional reductions in battery costs continue to bring EVs closer to parity with conventional vehicles for initial purchase price.

Table 7: Electric Vehicle Tax Credit Status by Manufacturer

Manufacturer	Total Vehicles Sold	% to 200K goal
Tesla	493,780	246.9%
GM (Cadillac and Chevrolet)	222,012	111.0%
Nissan	138,634	69.3%
Ford	118,285	59.1%
Toyota	111,401	55.7%
BMW N. America	90,713	45.4%
Honda	32,879	16.4%
FCA (Chrysler and Fiat)	28,759	14.4%
Volkswagen	17,010	8.5%
Kia	16,326	8.2%
Mercedes-Benz	15,336	7.7%
Audi	13,731	6.9%
Porsche	12,019	6.0%
Volvo	11,288	5.6%

Manufacturer	Total Vehicles Sold	% to 200K goal
Hyundai	10,736	5.4%
Smart USA	8,485	4.2%
Mitsubishi	8,184	4.1%
Jaguar Land Rover	2,235	1.1%
Subaru	496	0.2%

Source: Argonne National Laboratory. Data through September 2019. https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates.

State-level policy is another factor. An increasing number of states are adopting California's version of a Zero Emission Vehicle (ZEV) standard that requires major vehicle manufacturers of passenger cars and light trucks to attain a certain number of ZEV credits based on the number of vehicles produced and sold in the state. However, the federal government is trying to eliminate state ZEV policies. States with ZEV mandates are prioritized by automakers for EV inventories. States without these policies have far less inventory and choice of models. If more states adopt these policies and courts affirm their legality, Ohio and other non-ZEV states may see less growth in inventories and model choice. If federal action blocks or eliminates ZEV policies, overall EV sales may decline but Ohio may see modest growth in inventories and model choices. What happens will impact growth in ways that can't be predicted.

3. Outreach and Benchmarking

To determine where the state should focus any investment of time or resources in charging infrastructure, the team first spoke with Ohio utility organizations, other Ohio stakeholders, vendors and other state and federal agency leaders across the United States. The discussion focused on our planning process, understanding what they have accomplished to date and what their future EV charging plans are and determining if and how best to coordinate moving forward. Specifically, the team met with:

- **Utility Organizations**
  - Public Utilities Commission of Ohio (PUCO): regulates providers of electric and natural gas, local and long-distance telephone, water and sewer, rail and trucking companies. Sets rates for investor owned utility services.
  - American Electric Power Ohio (AEP Ohio): currently has a $10m EV infrastructure incentive program aimed at providing 375 public charging stations throughout the AEP Ohio service territory. Data gathered from this program will be used to help deploy charging across the greater 11-state AEP territory.
  - American Municipal Power – Ohio (AMP – Ohio): non-profit organization serving 85 municipal electric systems in Ohio.
  - Ohio's Electric Cooperatives (OEC): non-profit organization serving the 25 cooperatives in Ohio with representation in 77 of Ohio's 88 counties. They average 7 customers per mile versus the 30-40 customers per mile that investor owned utilities typically have.
- **Ohio Stakeholders**
  - Ohio Environmental Protection Agency (Ohio EPA): Administrator of Ohio's $75m Diesel Mitigation Trust Fund grant program (often referred to as the VW Settlement Grant program), $11.2m of which is designated for public EV charging infrastructure to be released soon. Twenty-six of Ohio's 88 counties will be eligible for VW funds.
  - Ohio Turnpike Infrastructure Commission (OTIC): installed DCFCs at 4 service plazas along western I-80 in northern Ohio through Electrify America https://www.ohioturnpike.org/travelers/service-plazas/electric-vehicle-charging and are looking to partner again for the installation of DCFC at all service plazas (7 in each direction) across their network.
  - City of Columbus: Through a grant from the Paul G. Allen Family Foundation and partner support, the program has increased the number of public charging ports in the Columbus region to 493 and has achieved coverage every 5 miles within Franklin county. The City has also purchased 200 EV fleet vehicles in the past 2 years and installed 102 charging ports for their EV fleet.
- **Vendors:** ChargePoint and Greenlots are two of the three vendors approved to support the AEP Ohio incentive program (EV Connect is the third approved vendor).
  - ChargePoint: Created the world's largest EV charging network over the last decade with over 104,200 charging locations. They install, operate and maintain charging equipment and software.
  - Greenlots: Provides turnkey solutions for EV charging with deployments in 13 countries and more than a decade of experience. Shell acquired them in 2019.

- **Other EV Leaders**
  - **U.S. Department of Transportation (USDOT):** The Federal Highway Administration is establishing Alternative Fuel Corridors along Interstates and U.S. Highways/State Routes.
  - **Colorado Energy Office:** Their three goals are EV infrastructure, ZEV adoption and public outreach/awareness. The 2018 Colorado EV Plan targets 940,000 EVs by 2030, an increase from the approximate 24,000 EVs on the road in 2019.
  - **Michigan Department of Environment:** Traffic volumes were primarily used to recommend a network of 70 DCFC stations/300 charging plugs and additional Level 2 facilities across the state.
  - **Minnesota Department of Transportation (MnDOT):** Their plan focuses on increasing EV adoption in MN from the approximate 10,000 EVs on the road in 2019 to 200,000 in 2030.
  - **Washington State Department of Transportation (WSDOT):** Planned and are implementing an EV charging program focused on DCFC access every 40-50 miles on Interstates.

Table 8 summarizes the take-aways from these meetings.

Table 8: Key Take-Aways from Outreach and Benchmarking Meetings

Topic	Advice
General	The state has an opportunity to help frame roles at the state, regional and county/city level. This will help parties know where to focus and invest their time or money.
	The average DCFC charging time at DCFC facilities across the U.S. is 27 minutes.
Outreach	Include stakeholders in the conversations. They will help identify and solve challenges early.
Site Selection	Be strategic in locating charging to fill gaps.
	Prioritize DCFC in FHWA Alternative Fuel Corridors to support intercity travel.
	Locate sites at least every 50 miles to meet the FHWA requirement to be signage ready.
	Locating chargers at rest areas will be challenging. Look for private site partners.
	Key criterion for DCFC is where the largest incentives are available. For Level 2 this is much less of a concern.
	Must have 3-phase, 480V power for DCFC locations.
	High traffic volumes are the main driver most organizations have used for locating charging.
	Choose easily accessible sites. WSDOT looked for sites within a half mile of the highway interchange.
Charging	Smart charging provides data which allows travelers to know if the chargers are available and allows the site hosts to understand usage patterns to help with future planning and operation.
	Charging technology is evolving quickly. Understand that in 5-10 years chargers will likely need to be upgraded.
Costs	Evaluate the expected level of demand charges early as they can be significant and it’s difficult to waive them.

4. Data Collection

Several data sets were collected to better understand and visualize the current DCFC infrastructure in the State of Ohio and determine the most suitable locations to deploy DC Fast Chargers to support Ohio's intercity travel and promote tourism.

- **County Boundaries:** Mapping the 88 Ohio counties made it easier to locate and sort recommended locations.
- **Road Network:** The Ohio inventory for Interstates, U.S. Highways, and major State Routes were mapped.
- **Traffic Measures:** Traffic information such as Annual Average Daily Traffic (AADT) and Vehicle Miles Traveled (VMT) were mapped to identify the most traveled routes.
- **Streetlight data:** Traffic data from Streetlight was used to analyze the number of trips to state parks and lodges.
- **EV Charging Infrastructure:** Data from the U.S. Department of Energy's Alternative Fuel Data Center, a database of existing EV charging stations, was mapped and supplemented with crowdsourced EV charging infrastructure data from apps like PlugShare.
- **Truck Stops/Gas Stations:** This data set was used primarily to identify large enough truck stops or gas stations to support the deployment of DCFC.
- **State-Owned Facilities:** ODOT rest areas, district facilities, and outpost garages were mapped. Offices and other buildings from the Department of Natural Resources, Department of Public Safety, Ohio History Connection, and Ohio Turnpike and Infrastructure Commission (OTIC) were identified and taken into consideration as possible siting locations.
- **Transportation Hubs:** Airports, ferry terminals, ports, park and rides and public transportation facilities were collected and mapped.
- **Attractions:** Amusement parks, sports venues, zoos, major shopping centers, museums, golf courses and state parks were mapped for possible locations to support intercity travel.
- **Utility Coverage Areas:** Coverage areas for Ohio's investor-owned utilities (American Electric Power Ohio, Dayton Power and Light, Duke Energy Ohio, and the First Energy distribution companies – Ohio Edison, Cleveland Electric Illuminating Company, and Toledo Edison), the 85 Municipal Power Companies, and the 25 different Co-ops around the State of Ohio were mapped.
- **Vehicle Registration Data:** Concentrations of electric vehicles registered in Ohio were mapped to understand ownership patterns.
- **Other:** Data sets with information on colleges and universities, fairgrounds, major hospitals, population, and urban areas were utilized.

See **Appendix D** for a full list of data sources utilized, including the year the data was collected.

5. Approach to Identifying EV Charging Priorities

Corridor charging, by definition, necessitates DCFC infrastructure because Level 2 charging requires several hours of dwell time, as opposed to a half hour for DCFC.

The following section describes the approach that was used, leveraging GIS, to identify gaps, find suitable locations, and prioritize the most critical sites for Ohio to invest in DCFC. This process focused on supporting intercity travel along Interstates, U.S. Highways and State Routes.

Level 2 charging prioritization methodology then focused on top attractions and other state-owned facilities in Ohio, as discussed in **Section 5.2**.

5.1. Direct Current Fast Charging

To be considered a signage ready alternative fuel corridor by the FHWA, Interstates, U.S. Highways, and State Routes must have charging infrastructure at least every 50 miles. So, Interstates, U.S. Highways and State Routes were evaluated to determine where there were gaps in DCFC infrastructure of more than 50 miles. Based on traffic volumes, the first focus for corridor charging was the Interstates. Once gaps in the Interstate system were identified, U.S. Highways and State Routes with AADTs over 15,000 were evaluated.

Table 9 shows existing chargers within 0.5, 1 and 1.5 miles of the Interstate/US/SR system by port type (see **Appendix B** for port type details). As of April 2020, there are 250 DCFC stations within 0.5 miles of Ohio's Interstate/US/SR system and 281 DCFC stations within 1.5 miles of the Interstate/U.S./SR system. A 1-mile threshold, slightly longer than the threshold of 0.5 mile used by Washington state, was ultimately used as it represents a reasonable distance to travel off the Interstate/U.S./SR system for charging while still being generally within the network and existing signage areas.

Table 9: Public Direct Current Fast Charging Stations in Ohio

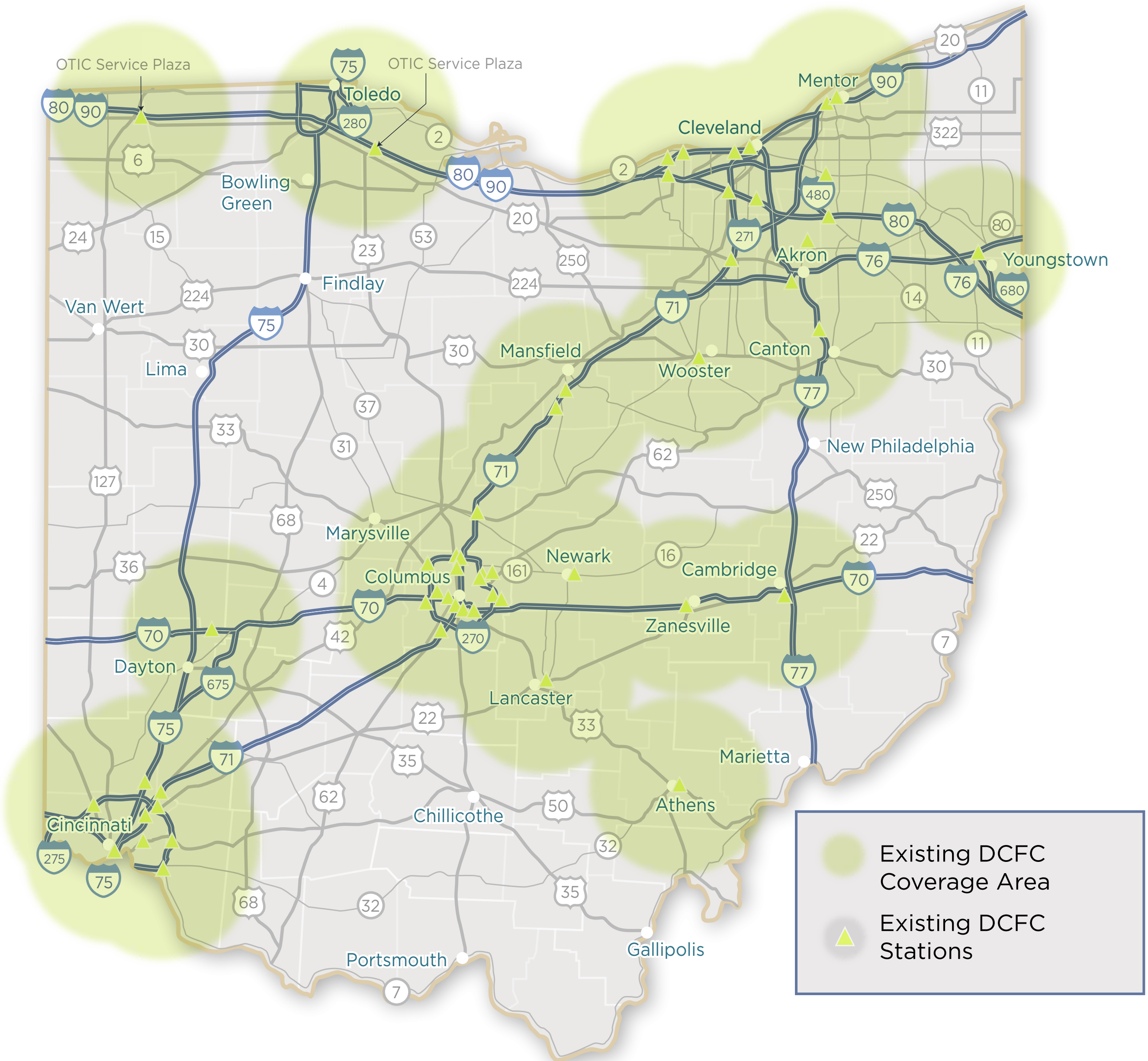
		Charging Stations within X miles of Interstate/U.S./SR System*		
Connector Types	**Total Stations***	**Within 0.5 miles**	**Within 1 mile**	**Within 1.5 miles**
CHAdeMO Only	7	6	7	7
CCS Only	6	6	6	6
CHAdeMO & CCS	123	96	115	118
Tesla	150	142	150	150
Total	**286**	**250**	**278**	**281**

* *In this instance, 'stations' represent the number of vehicles that can charge at one time at the given location*

Note: This project excludes Tesla Chargers and private businesses/limited-hour chargers. Accessed April 2020.
***** *U.S. Highways and State Routes roads with AADT >15,000*

Figure 9 indicates the existing DCFC infrastructure within 1 mile of the Interstate system and shades the approximately 50-mile coverage area. For existing DCFCs represented in **Figure 9** please refer to **Appendix E**. The infrastructure shown in **Figure 9** only includes 24/7 publicly available facilities, therefore omitting DCFCs at car dealerships or other businesses with limited availability. This study does not include Tesla Superchargers since non-Tesla vehicles cannot use these chargers. In addition, Tesla vehicles have longer ranges on average when compared to other EV makes/models, their charging network is more robust, and their vehicles are able to use other charging networks if needed.

Figure 9: Ohio DC Fast Charging Infrastructure within 1 mile of Interstate/U.S./State Route* Systems



5.1.1 Interstates

After importing the data sets mentioned in **Section 4**, the following approach was used to determine the best locations for DCFCs on the Interstates:

Step 1: Identify existing public DCFCs within one mile of the Interstate system.

Step 2: Create a 20-mile radius buffer around the current DCFC identified in step 1 to identify gaps of more than 50 miles between DCFC along the Interstates. To account for the difference between actual roadway travel distance and straight-line distance, buffers of 20 miles (rather than 25 miles) were used. See **Figure 9**.

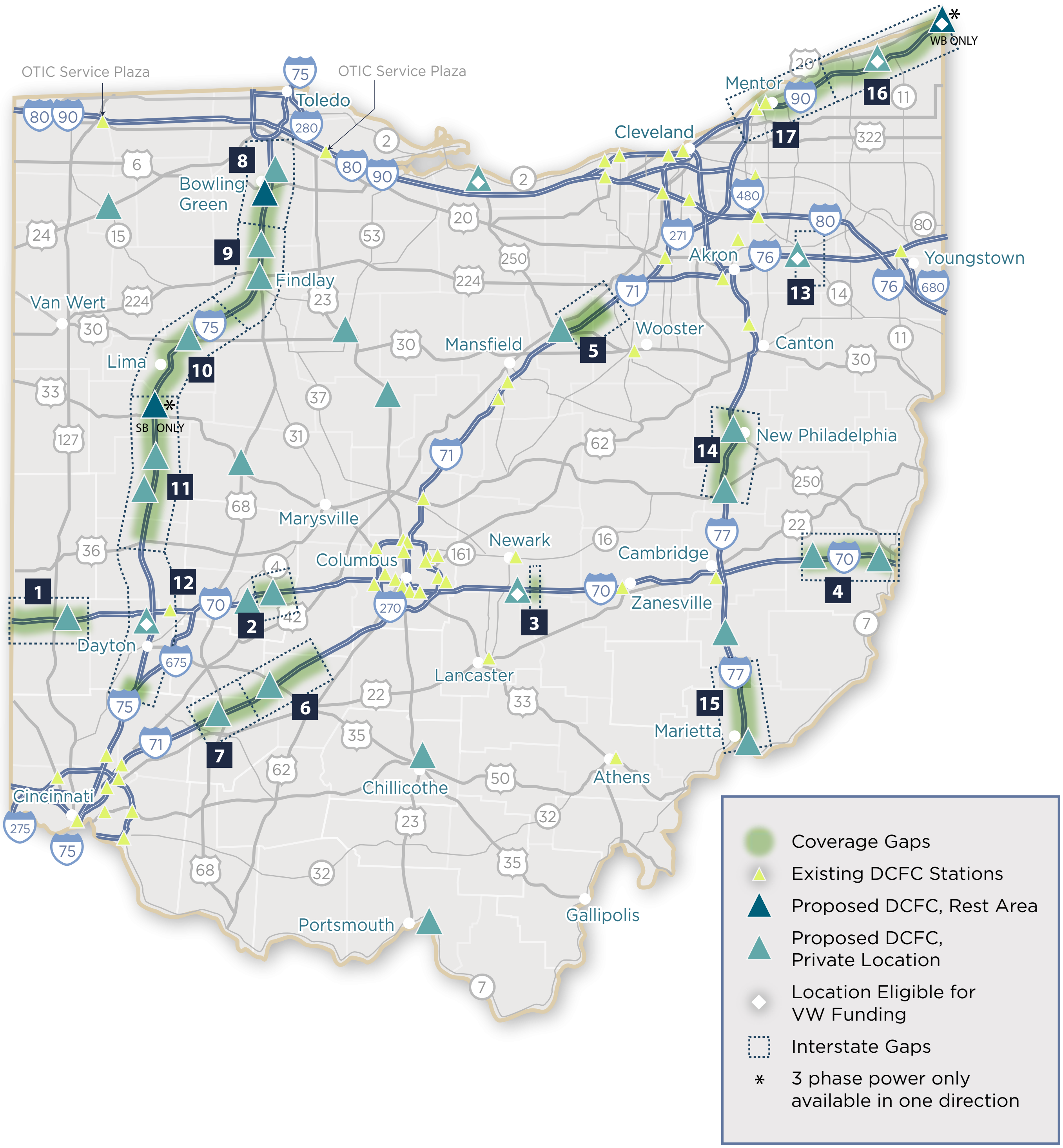
Step 3: Label the identified gaps. See the Interstate gaps labeled by number as shown in **Figure 10**. *Note: Gaps along the Ohio Turnpike are included separately in* ***Figure 14.***

Step 4: Identify possible DCFC locations to fill the gaps. Preferred locations:

- Have ample parking.
- Are within 1 mile of the corridor.
- Are adjacent to restaurants or other amenities for drivers to visit while the vehicle charges.

Step 5: Identify which utility provider serves each possible DCFC location using GIS data and coordinate with them to confirm that 3-phase power is available.

Figure 10: Current Gaps along Ohio's Interstates



5.1.2 U.S. Highways and State Routes

To further strengthen the state network the following approach was used to determine the best locations for additional DCFCs along U.S. Highways and State Routes:

Step 1: Identify the U.S. Highways and State Routes that encounter the most traffic by filtering for corridors with more than 15,000 AADT.

Step 2: Map existing public DCFCs within one mile of any U.S./State routes – not just the segments identified in step 1.

Step 3: Create a 20-mile radius buffer (as described in **Section 5.1.1**) around the existing infrastructure found in step 2 to ensure chargers are no greater than 50 miles apart.

Step 4: Identify and label the current gaps in the network segments identified in step 1.

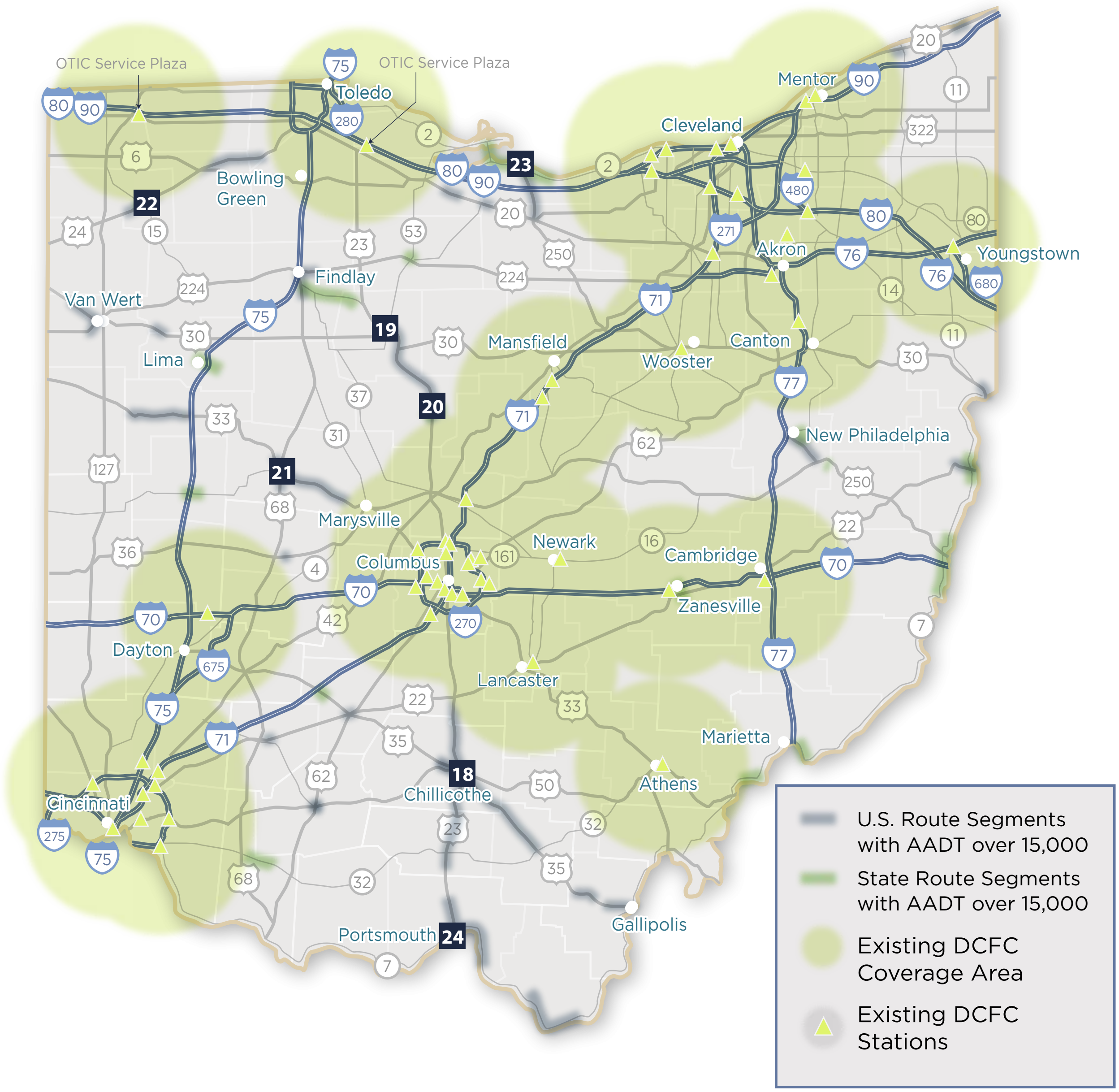
Step 5: Identify possible DCFC locations to fill the gaps. Preferred locations:

- Have ample parking
- Are within 1 mile of the corridor
- Are adjacent to restaurants or other amenities

Step 6: Identify which utility provider serves the recommended locations and coordinate with them to confirm availability of 3-phase power.

For existing DCFCs represented in **Figure 10** please refer to **Appendix E**. **Figure 11** shows U.S. Highway and State Route segments with AADTs over 15,000 and identifies existing DCFC infrastructure within a mile of these routes. **Appendix F** compares AADTs of 5,000+, 10,000+, 15,000+, and 20,000+ on U.S. Highway and State Route segments in Ohio.

Figure 11: Direct Current Fast Charging Infrastructure along U.S./State Routes



Again, it is important to note that the existing infrastructure mapped in **Figure 11** does not include any Tesla Superchargers or DCFCs that are in dealerships or other sites where 24/7 accessibility is negated.

5.2 Supplemental Level 2 Analysis

To support state tourism Level 2 charging stations at top state attractions were also evaluated. This would allow for EV owners to drive comfortably to a destination in which they know they will be able to charge their cars for longer periods of time. To determine the most appropriate locations for the state of Ohio the following approach was taken:

1. Collect various sources of top attractions around the State of Ohio (Ohio Traveler, Ohio Tourism, Google Trips, The Crazy Tourist, PlanetWare, Cleveland.com, and Top Ohio Parks).
2. Calculate the number of occurrences of each attraction across the different sources.
3. Catalogue existing EV infrastructure for any attractions that appear on two or more lists.
4. Identify top priority sites for Level 2 charging if the site was a state facility or outside of a major Ohio metro area.
5. Top attractions within urban areas were selected based on the lack of existing charging around the sites having the most occurrences – most having multiple co-locating attractions.

Section 6.2 shows the recommended Level 2 charger locations. More information about the process used can also be found in **Appendix G**. See **Appendix H** for Ohio State Park zone activity analysis using StreetLight Data.

5.3 Charging Infrastructure Incentives

Governments and private companies are providing financial support to develop EV charging in Ohio. This includes DC fast charging (DCFC) in publicly accessible locations as well as workplaces, multi-unit dwellings (MUD) and for EV fleets. Each program has distinct eligibility rules based on geography, types of EV charging, and required matching funds. **Table 10** shows the funding sources that are currently or soon to be supporting projects. See **Appendix I** for more details.

Table 10: Electric Vehicle Charger Incentives and Funding Sources

Source	Type	Eligibility	Notes
AEP Ohio	Utility	AEP Ohio Territory	Existing: Level 2 public, MUD, workplace, DCFC, $10 million total
Duke	Utility	Duke Territory	Potential Future: Filed, pending PUCO action, $15 million, DCFC, Level 2 public, MUD and workplace
Electrify America	Private	Ohio Interstates	Existing and Future: Timing to be determined
Ohio EPA (VW Settlement Grant program)	State	Future, Select Counties	Future: 2020, round one Level 2, round two DCFC, $12 million total
Municipal and Co-Op Utilities	Utilities	Any site type	Potential Future: Subject to approval by utility boards
NOACA	Regional	Cleveland Area	Future: Funding approved, expected to be mostly Level 2, details pending
Regional Planning	Local	Public Access	Potential Future: EV charging is an eligible use of CMAQ funding
Smart Columbus	Public/Private	Central Ohio	Existing: Level 2 MUD only
USDOT	Federal	Travel Corridors	Potential Future: Proposed $300 million national program, may be added to reauthorization of federal transportation bill in late 2020

Source: Clean Fuels Ohio

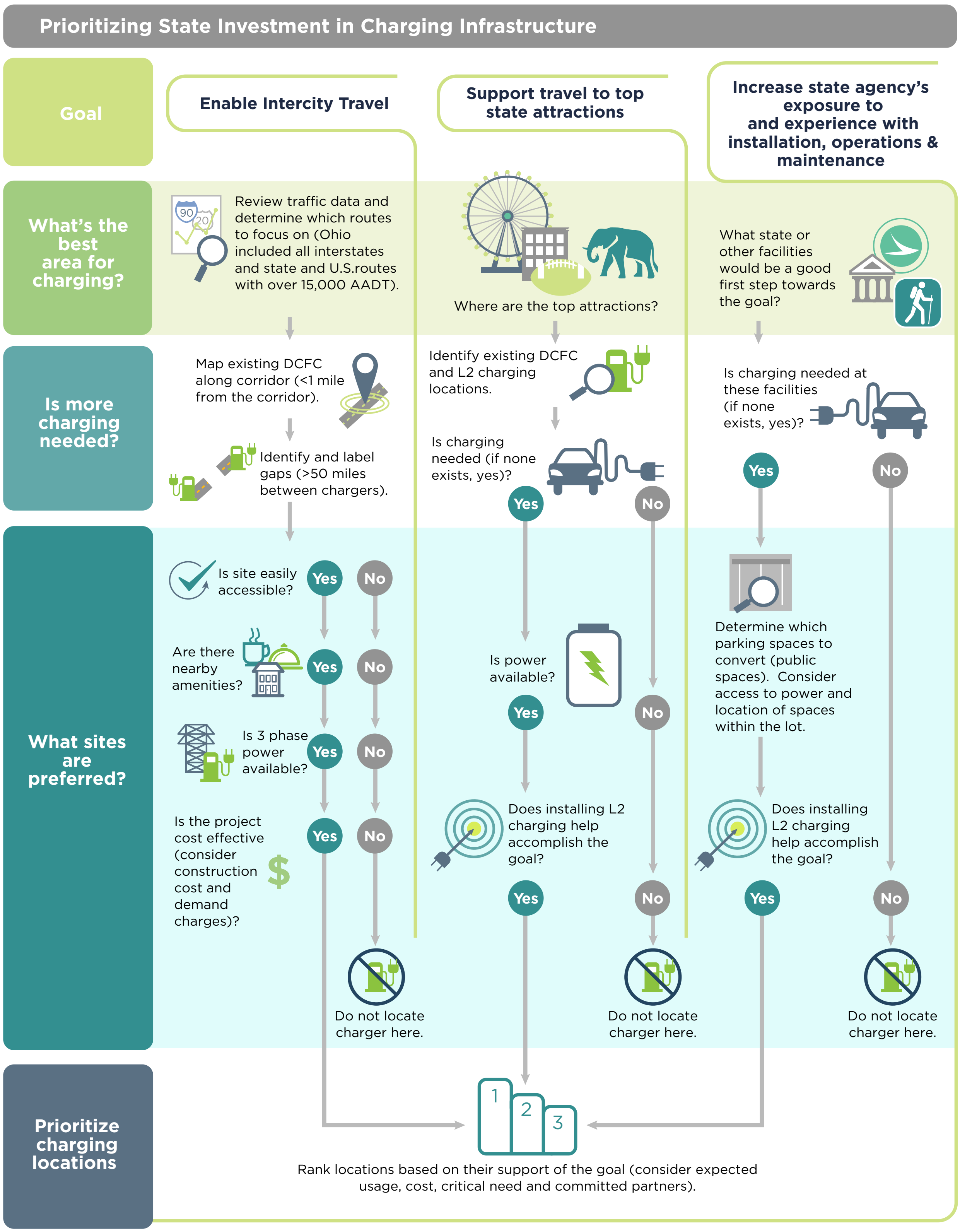
6. Key Insights and Implementation Recommendations

The purpose of this report is to assess needs for EV charging, focusing primarily on Ohio's highway corridors. As stated earlier, corridor charging requires relatively high-power DCFC facilities at locations that are easily and quickly accessed by EV drivers. Some of these sites exist today in Ohio. This report identifies the gaps in corridors along Ohio where DCFC is necessary and identifies options to fill them. Most of these gaps should and will need to be filled by private commercial site hosts but some gaps have the potential to be supplemented by ODOT rest stops and OTIC service plazas if adequate electrical infrastructure exists.

An important supplemental purpose is identification of destination charging needs. This is not corridor charging but helps facilitate long distance travel and Ohio tourism by ensuring that EV motorists are able to recharge their vehicles while they are visiting their destination.

A final objective is to assist ODOT and other state agencies such as ODPS, ODNR, and OTIC in establishing EV charging to gain direct experience and insight in this field and demonstrate support for this enabler of future mobility. **Figure 12** summarizes these three charging goals and the process of analyzing and recommending locations.

Figure 12: Process for Identifying Public Charging



6.1. Recommended Direct Current Fast Charging Sites

6.1.1. Site Selection

The most suitable locations for DCFC are private commercial facilities located immediately off highway exits. Examples include larger truck and car service stations with attached dining, retail stores, and tourist attractions. These sites are best for three primary reasons:

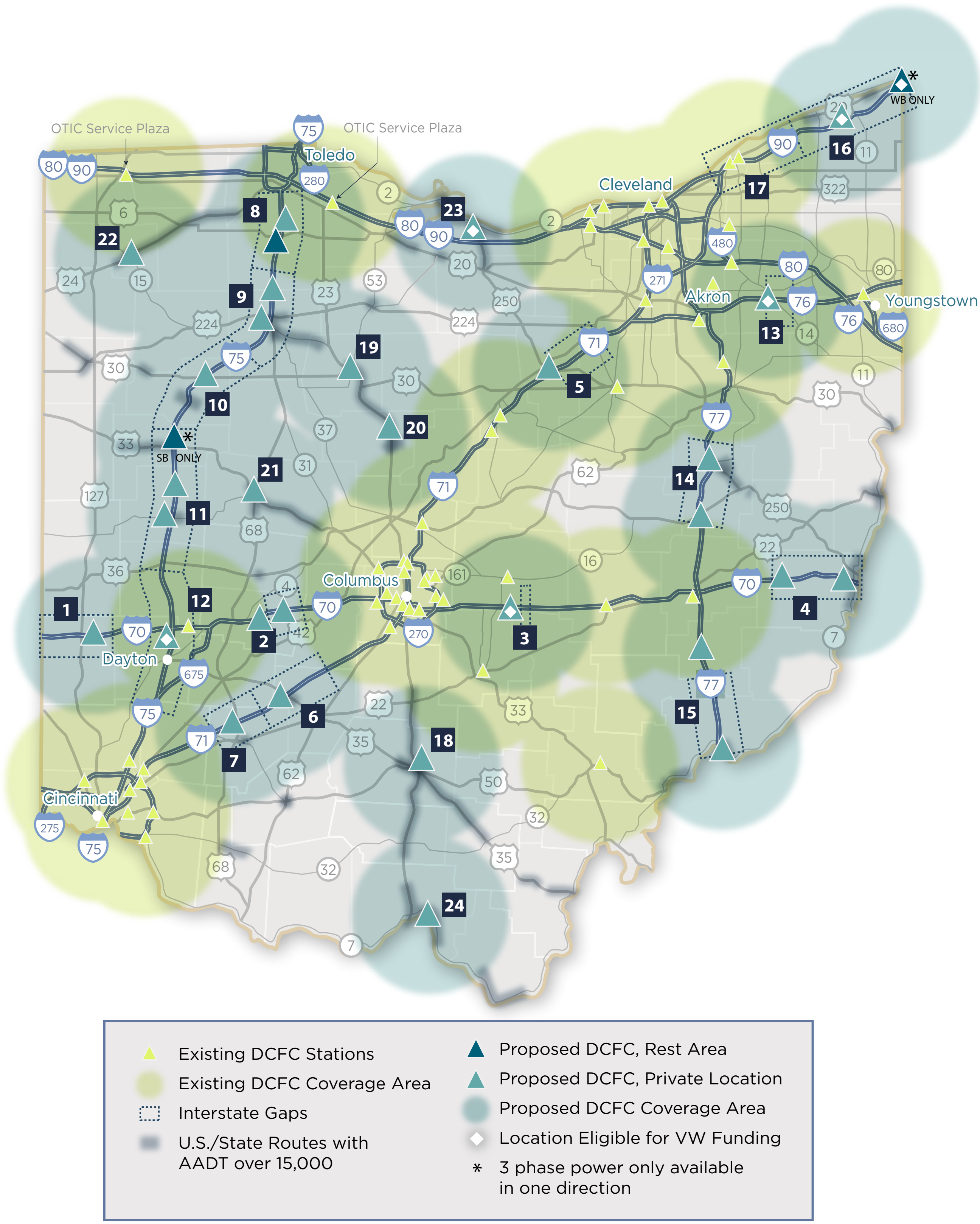
1. Proximity to highway.
2. They offer amenities to consumers while they charge their vehicles. Note: Current 50 kW and 90 kW charging rates require at least 30-40 minutes to charge, and the next incremental standard of 150 kW still will require about 20 minutes. The 350 kW rate will approximate the time required to refuel a gasoline vehicle. Time also is a function of battery size.
3. They are more likely to already have utility power supply required.

On the contrary, exits with only small gas stations don’t offer the same consumer amenities, and typically lack adequate power.

Similarly, state rest stops are designed to provide restroom facilities and vending machines and therefore typically lack adequate power for DCFCs. State-owned rest stops face an additional barrier of being prohibited from directly billing customers for the electricity used to charge or offer any amenities other than vending machines. Developing DCFC at state-owned rest stops can also be perceived as placing the state in competition with the private sector. However, given these potential barriers, rest areas can provide motorists with the most convenient option for charging since the facilities are directly on the highway. Of the 17 total interstate gaps identified, 11 rest areas were within the gaps. Of the 11 rest areas, only three have available 3-phase power, two of which are only serving one direction.

Based on the analysis in Section 5.1, several options for DCFC locations were identified to fill the gaps. **Figure 13** shows existing DCFC corridor sites and gaps. **Appendix J** shows the lists of top recommended sites and highway exit locations along with a few state-owned facilities for focused efforts aimed at facilitating EV intercity travel.

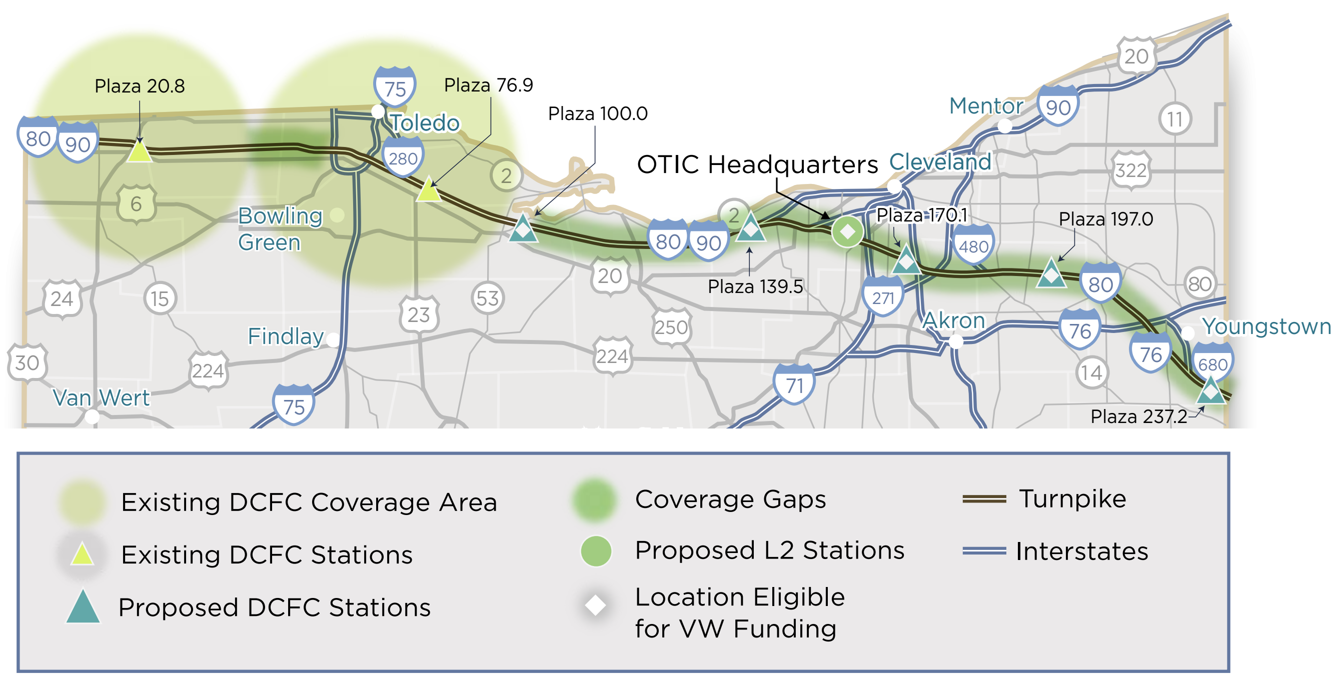
Figure 13: Recommendations for DC Fast Charging in Ohio



Each gap where rest areas are an option also includes options for private locations off the interstate. Helping to facilitate private sector commercial development of DCFCs while, in parallel, exploring the feasibility of DCFCs at the noted rest stops will help fill these gaps. Coordinating with the Ohio EPA and the Public Utilities Commission of Ohio will be key to making this effort a success.

A separate analysis, similar to the one described above, was conducted for the Ohio Turnpike and Infrastructure Commission to identify gaps along the Turnpike. With limited access along the corridor, service plazas offer the most convenient electric vehicle charging stations and have a variety of amenities for EV drivers to utilize while charging their vehicles. As of April 2020, the four westernmost service plazas (MP 20.8 and MP 76.9) have DCFCs available in each direction. Using the same criteria for the Interstates and US/State Routes of having no more than 50 miles between DCFCs, but not including existing DCFCs within a mile of the corridor (due to access constraints), two coverage area gaps were found along the Turnpike. The first coverage gap is between the two existing DCFC coverage areas. However, it is not recommended to fill this gap with chargers since the gap is relatively short (about 6 miles) and doesn't have an existing service plaza so it would require chargers to be installed at a private location off Exit 52. The second coverage gap extends east of the service plazas at MP 76.9 along the Turnpike to the state line with Pennsylvania since no charging currently exists at any of the other service plazas. Because the remaining service plazas are spaced within 50 miles of each other, it is recommended that DCFC stations be placed at each service plaza along the Turnpike (both directions of travel) to fill the gaps and encourage EV intercity travel. A map showing the existing DCFCs and proposed DCFCs along the Ohio Turnpike is shown below in **Figure 14**.

Figure 14: Current Gaps and Recommendations for DC Fast Charging along the Ohio Turnpike



Of the 14 total service plazas (one in each direction) on the Ohio Turnpike, four service plazas already have DCFCs. The remaining 10 service plazas are recommended for DCFCs to fill the remaining coverage gaps along the Turnpike.

6.1.2. Utility Coordination

There are three categories of utility organizations in Ohio (refer to **Appendix J**)

- **Investor owned:** For-profit power providers owned by stockholders who may or may not be customers or live in the service area. The investor owned utilities include AEP Ohio, Dayton Power & Light, Duke Energy Ohio, and the First Energy distribution utilities - (including Cleveland Electric Illuminating Company, Ohio Edison, and Toledo Edison).
- **Co-ops:** Not-for-profit cooperative power providers are owned by their members and only provide power to their members. Co-ops are not regulated by the Public Utilities Commission. Five of the recommended sites are serviced by co-ops (Consolidated Electric, Hancock Wood Electric, Midwest Electric, Pioneer Electric, South Central Power, Washington Electric).
- **Municipal utilities:** A public power system owned by a municipality. Municipal utilities are not regulated by the Public Utilities Commission. Coordination with municipal utilities were not required based on the finding for recommended chargers in this study.

The state can support investments in charging infrastructure by continuing to establish a point of contact at each investor owned utility, AMP and OEC and facilitating conversations between these organizations and the site hosts. Creating a mechanism to evaluate proposed charging locations will help support site hosts as they work through the development and installation process. A few specific items to coordinate include:

- Site hosts providing estimated charging loads (kW), as well as an estimated duty cycle (kWh) to utility providers.
- Electric providers or authorities having jurisdiction (if co-op or muni) providing power availability (or rough magnitudes and estimated lead time and cost) as well as applicable rates and demand thresholds. Proposed alternative solutions should also be encouraged from power providers.
- Development of a matrix which can be shared between all parties to show common approaches to installing charging and notes any challenges and/or opportunities.

6.2. Recommended Level 2 Charging Sites

6.2.1. Ohio Attractions

Figure 15 shows the recomended Level 2 charger locations. These sites were determined as a result of the analysis detailed in Section 5.2 and will allow visitors to travel directly to and from the attraction and charge their vehicles at a slower rate for the hours they spend visiting the attraction. It is suggested to locate at least two Level 2 charging units with two plugs each at recommended attractions. This will require the allocation of four public parking spaces.

Figure 15: Recommendations for Level 2 Charging at Ohio Attractions and State Agencies

6.2.2. Ohio Agencies

To assist with public and agency awareness this study also considered how to best integrate charging at agency facilities. It is recommended to locate at least one Level 2 charging unit with two plugs at each ODOT District Office and Central Office. These chargers should be in an area available to the public and employees. See **Figure 15** and **Appendix K** for the ODOT district locations. District office leadership will need to identify which two public parking spaces should be allocated for EV charging and coordinate installation.

In addition to the ODOT district offices, public Level 2 charging is also recommended at some ODNR, ODPS and OTIC facilities:

- ODNR
  - Charging is recommended at each of the 8 state parks with lodges as an added amenity to visitors. These lodges are a priority since they have adequate power and offer overnight accommodations. Each of the eight state park lodges would have two dual-port Level 2 charging units installed.
  - Three other popular state parks without lodges, Caesar Creek, Hocking Hills, and Marblehead Lighthouse, were also prioritized for two dual-port Level 2 chargers based on visitation data.
- ODPS – Three high-traffic locations are recommended in Franklin County with each facility installing one dual-port Level 2 charger. These includes headquarters at the Charles D. Shipley Building, an Alum Creek Rd. facility (where there is a high-volume BMV facility), and the Emergency Management Agency facility on Dublin Granville Rd.
- OTIC – One dual-port Level 2 charger is recommended at their headquarters in Berea, OH.

6.3. Cost Assumptions

Figure 16 shows all the recommended charging locations identified. The associated costs assume one installation per interstate gap identified; (with up to 3 recommended locations each). A minimum of two dual-port chargers (1 CCS port and 1 CHAdeMO port per charger) at each of the DCFC sites is advised. One dual-port L2 charger (2 J1772 ports per charger) is recommended at each ODOT District Office and Central Office (13 total chargers), two dual-port L2 chargers at each of the 11 ODNR state park facilities (22 chargers), one dual-port L2 charger at the three ODPS facilities (3 chargers), and one dual-port L2 charger at OTIC headquarters. A minimum of two dual-port L2 chargers are recommended for the eight Ohio attraction locations (16 chargers). The greatest cost variable will be the make-ready work for power service.

Figure 16: Recommendations for Direct Current Fast Charging and Level 2 Charging

Table 11 summarizes the cost assumptions used for DCFC and L2 chargers. Table 12 shows the estimated cost of installing chargers at all the recommended locations ranging from about $2.3 million ($2.0 million plus $0.3 million) to $4.4 million ($3.6 million plus $0.8 million). Approximately 50% of these costs are within counties eligible for VW

funding support through the Ohio EPA, potentially bringing the overall charger and installation costs down to between $1.1 million and $2.0 million. For information on Ohio Department of Administrative Services Electric Vehicle Chargers and Equipment universal term contract options see the following website: https://procure.ohio.gov/proc/viewContractsAwards.asp?contractID=36761

Table 11: Electric Vehicle Charger Cost Assumptions

	DCFC (50 kW)	Level 2
Cost per charger	$25,000-$35,000	$2,605-$6,190
Make-ready work cost per site	$10,000-$40,000	$4,000-$12,000
Annual O&M costs per charger*	$1,400-$2,000	$1,000

** Not included in cost estimate.*

Table 12: Electric Vehicle Charger Cost Estimate by Agency

Charger/Location Type	Recomm'd Locations	Number of Dual-Port Chargers	Locations Eligible for VW Funds	Cost Estimate without using VW Funds	Potential Cost Estimate using VW Funds
Level 2: Attractions	8	16	8	$73,680-$195,040	$0
Level 2: ODNR State Parks	11	22	5	$101,310-$268,180	$55,260-$146,280
Level 2: ODPS Locations	3	3	3	$19,815-$54,570	$0
Level 2: OTIC Office	1	1	1	$6,605-$18,190	$0
Level 2: ODOT District Offices	13	13	6	$85,865-$236,470	$46,235-$127,330
Level 2: Total	**36**	**55**[a]	**23**	**$287,275-$772,450**	**$101,495-$273,610**
DCFC: ODOT Rest Areas	16	32	1	$960,000-$1,760,000	$660,000-$1,210,000
DCFC: Private Sites (IR)			4		
DCFC: Private Sites (US/SR)	7	14	1	$420,000-$770,000	$360,000-$660,000
DCFC: OTIC Service Plazas	10	20	10	$600,000-$1,100,000	$0
DCFC: Total	**33**	**66**[b]	**16**	**$1,980,000-$3,630,000**	**$1,020,000-$1,870,000**
Totals	**69**	**121**	**39**	**$2,267,275-$4,402,450**	**$1,121,495-$2,143,610**

[a] All Level 2 charging stations will allow 2 vehicles to charge at one time and will meet the J1772 standard.
[b] Dual-port DCFC includes 1 CHAdeMO port and 1 SAE CCS port to ensure that all BEVs can connect. One car can charge at a time.

6.4. Schedule Considerations

The process and timeframe for applying for funding for EV charging, then installing facilities can vary widely, depending on the funding source and project specifics. Generally, Level 2 projects are faster and more straight-forward unless they involve many plugs, requiring network engineering and large power supplies. DCFC facilities take longer to complete.

For the recommended Level 2 destination charging projects that qualify for funding, assume 60 days for Ohio EPA or another funder to review and make an award determination, then another 30-60 days for the contracting process, which must be completed before any work on the project can begin. Once contracts are executed, installation timing will depend on the time of year and installation requirements. Project site hosts may need to issue a solicitation and review bids from competing equipment providers and installers. An electrical supply site assessment is needed. Once all the preliminary steps are completed, the process to install the charging can generally be completed in three to five months. Thus, the total time from application submission to completed project could be as long as nine months.

For DCFC corridors, site hosts likely will need to work more closely with the utility on power supply and other complexities. If all parties are very aggressive, a nine-month timeframe may be achievable, but a more realistic timeframe is 12-15 months.

6.5. Operational and Maintenance Considerations

It’s important for site hosts to understand various operational and maintenance (O&M) considerations before embarking on any project. Educational materials should be provided to potential site hosts for a better understanding of operational and maintenance considerations. Additional assistance and support through planning, installation, design, and operations by the charging vendor is crucial to long term success. These are important for all charging types but especially for DCFC. Failure to plan can lead to unanticipated operational expenses. The issue of demand charges is especially critical to understand and can vary widely by site. Typically, a site host will contract with a vendor to handle O&M at a cost. That vendor may be the same company that sold and/or installed the equipment, but it can be another company. The vendor may also offer a warranty package that would cover a limited number of parts and damage scenarios. Here is a listing of the key O&M considerations:

- Per kWh Cost of Electricity
- Electricity Demand Charges
- Communications and Networking Capabilities
- Common Consumer-Friendly Payment Systems
- Pricing and Payment Models for Use
- Pricing and Operating Signage
- Monitoring Reports About Station on Common Apps Such as Plugshare
- Interoperability Between Different Charging Provider Networks
- Ease of Access (including pull-through spaces for vehicles pulling trailers), Lighting and Other Site Design and Customer Safety Considerations
- Remote Troubleshooting and Resetting
- Routine Maintenance
- Early Notification of Service Issues and Rapid Response

6.6. Electric Vehicle Charger Ownership and Payment Models

Management activities for a station or cluster of stations might include managing driver access, billing, providing driver support, and monitoring the station. Renting or leasing a location, such as parking spots, can be an added operational cost if the charger owner does not own the property. The value of a parking space will vary widely depending on geographical location.

A growing number of vendors not only sell charging stations, but also offer installation and ongoing service and maintenance. Some vendors of charging units require drivers to subscribe to a charging service that uses credit card, cash, or radio-frequency identification (RFID) devices to control access to the charger and to enable the owner of the charger to collect usage data and payments for charging. Owners can also set up charging to be free for all or some users. Some charging vendors share in the revenue generated by the charger and charge service fees for managing payment transactions, maintenance, and trouble-shooting services.

Some charging site hosts may decide to purchase, install, and operate stations themselves. This model gives the host or owner control of the station and its revenues. For example, a parking lot owner might buy and operate a pay-for-use charging station as part of its business strategy.

Table 13: Electric Vehicle Chargers: User Fee and Payment Models

Model	Description
Free Charging: Consumer/User Amenity	EV Charging station and electricity consumed is free of charge for vehicle users. Usually this option is preferred for Level 2 charging stations in locations where consumers (i.e. retail store customers), employees, or residents of apartments can enjoy the charging stations as an amenity.
Time of Use Fees (Minutes, Hours)	EV Charging station assesses a time-based fee for parking (i.e. $/hour) and does not charge for electricity consumed by vehicle. This is by far the most common method of payment/fee structure today for Level 2 chargers.
Energy Use Fees (Electricity kWh)	EV Charging station sells electricity by kWh or MJ, and vehicle users are charged based on electricity consumed by vehicle. This method is preferred in DC Fast Charging locations. Given that DC Fast Chargers are capable of 50kW of electricity dispensed per hour, energy use fees are the most equitable way to pass along the costs of charging to consumers.
Combination Fee (Time + kWh)	EV Charging station assesses a time-based fee for parking (i.e. $/hour) and charge fees for electricity by kWh or MJ, and vehicle users are charged based on electricity consumed by vehicle.

6.7. Policy and Administration Considerations

The Ohio Department of Agriculture has updated rules for the method of sale of transportation fuels. Included in these updated rules is the sale of electricity to vehicles as motor fuel. The specific Section 901:6-5-02v1 of the Ohio Administrative Code can be found here: http://codes.ohio.gov/oac/901:6-5-02v1.

The rule requires EV charging station owners to post the "Method of Sale" at each charging station (i.e. is the station fee based on time, energy dispensed, or is the station free).

For any EV charging station that costs money for vehicles to charge, signage detailing the method of sale (i.e. sale by kWh of electricity consumed, sale by unit of time for parking, sale by a fixed fee, etc.) must be posted in reasonable proximity for the customer (i.e. within plain sight, easy to view when using station). The sign must detail both the method of sale, and the price per unit of sale for customers (i.e. $/kWh, $/hour, etc.).

6.8. Future Proofing

As discussed in Section 2.3, EV charging technologies are expected to advance over the next ten years in parallel with advancements in car battery technologies, specifically capabilities of batteries to accept faster rates of charge without degrading. As capabilities increase, consumers will demand faster rates of charge and become frustrated with and avoid sites that offer slower rates. Technologies will become obsolete. Thus, “future proofing” of DCFC stations is an important design consideration for any station developed today.

This means ensuring necessary levels of power can be provided and circuits can carry higher power. For example, sites today that may provide 50 kW charging rates should be designed so they are capable of being upgraded to 150 kW and eventually to rates up to 350 kW or 400 kW. Failure to plan for faster rates of charge might render stations obsolete or require more costly upgrades of wiring, conduits, and panel capacity.

7. Next Steps

To deliver the recommendations in this report and continue progress towards supporting interstate travel, routes with high AADT, and tourism in Ohio the following items can be initiated or continued:

- Socialize this study with other state agencies, MPOs, utilities, and other key stakeholders.
- Conduct outreach to highest priority sites, identify site hosts interested in applying for funding and assist with funding applications
- Establish a point of contact at each investor owned utility and Ohio's Electric Cooperatives (OEC) and facilitate more detailed conversations between these organizations and the site hosts to ensure the cost of providing power and the rates are not prohibitive and the process can move forward efficiently.
- Develop more detailed cost models and schedules based on ownership decisions.
- Facilitate efforts noted in **Table 14** to help Ohio agencies target the most impactful EV readiness activities. The state can further develop this framework to support their constituents.

Statewide and even interstate corridor charging planning is one part of a larger EV charging planning framework. Besides development of charging for intercity travel on highways, planning is needed at the regional level and at the individual community level. The state government can facilitate and encourage regional and local planning while also conducting statewide corridor planning. Each level involves its own site characteristics, facility types, users, and policy issues. Each type helps overcome the market barrier in different ways. Because of this, it is recommended that EV planning requirements be established on these state, regional, and local levels.

Intercity corridor charging facilities are located as close as possible to highway exits and designed to provide the fastest possible rate of charge to enable travelers to get back on the road toward their destinations. Ideally, these facilities should be located at or near attractive, useful consumer amenities. Their existence enables consumers to purchase and use battery EVs for long distance travel.

Regional EV charging planning is focused on urban/suburban DC fast charging sites (DCFC) and complementary public Level 2 charging. Unlike DCFC on highway corridors, those serving urban regional markets will be used increasingly by a variety of shared mobility services (taxis, transportation network companies such as Uber and Lyft, ride sharing and car sharing) that will find it increasingly attractive to shift to battery EVs. They also will be used by fleets that transition to EVs and occasionally by individual motorists.

Local EV charging planning requires development of a template that cities, counties, villages and townships can use. The template will identify policies, such as parking regulations, building codes, charging in rights of way and others. It also will help communities identify and engage developers and owners of multi-unit residences and workplaces where charging can or should be installed.

Table 14: Framework for Roles in Supporting EV Adoption

	State	MPO/Regional	County/City
Adoption	• Maintain a list of available EVs on the market (ODPS/Ohio BMV). • Provide latest trends on EV adoption by zip code, city and county to local and regional agencies (ODOT). • Add (ODAS) and publicize to Ohio agencies EV vehicle models that are on the states universal term contract list. • Consider offering EV purchase incentives. • Evaluate state fleet and duty cycles to determine which vehicles may be appropriate for conversion. • Ensure state vehicles have telematics capable of reporting state of charge and other key indicators.	• Publicize to member agencies EV vehicle models that are on the states universal term contract list. • Educate members on needed local policies and encourage adoption. • Educate elected officials and staff on fleet electrification. • Provide forums to consider electrification of government fleets and strategies to incentivize electrification of private fleets.	• Set local fleet electrification goals. • Analyze opportunities to add EVs to local government and other fleets. • Consider, then clarify/adopt EV parking, signage and other regulations. • Ensure vehicles have telematics capable of reporting state of charge and other key indicators.
Charging	• Plan EV corridor charging: gap identification, power supply analyses, priority locations for private sites. • Identify top destination targets for charging. • Develop state-owned sites for corridor DCFC. • Maintain and publicize to Ohio agencies EV chargers that are on the states universal term contract list. • Facilitate (PUCO) utility EV charging programs and adopt EV-related policies and goals. • Develop template for local EV charging planning. • Update state building code for parking garages to facilitate minimum % of "make ready" wiring.	• Identify gaps in regional DCFC charging network, based on shared mobility services and fleets. • Help identify private or government site hosts to fill DCFC gaps. • Identify additional L2 locations based on traffic flows and site characteristics. • Facilitate project partnerships with utilities, EV charging providers and installers to develop facilities. • Consider establishing EV charging incentives.	• Develop community-based EV charging plan addressing multi-unit dwelling, workplaces, public and fleet charging. • Identify priority locations (government, private); set goals for development. • Enact local policies such as "right to charge," "make ready" building codes for new builds and renovations, charging facilities in rights of way, others.

Appendix A. Electric Vehicle Model Availability

Make/Model	Fuel Type	Availability
Audi A3 e-tron / Ultra PHEV	PHEV	No longer available
Audi e-tron EV	EV	Available now
BMW 330e	PHEV	No longer available
BMW 530e Sedan	PHEV	Available now
BMW 530e xDrive Sedan	PHEV	Available now
BMW 740e xDrive	PHEV	Available now
BMW 745e xDrive	PHEV	Available now
BMW ActiveE	EV	No longer available
BMW i3/ i3s	EV	Available now
BMW i3/ i3s Range Extender (REX)	REEV	Available now
BMW i8	PHEV	Available now
BMW X5 xDrive40e PHEV	PHEV	No longer available
BMW X5 xDrive45e PHEV	PHEV	Available 2020
Cadillac CT6 PHEV	PHEV	Available now
Cadillac ELR	REEV	No longer available
Chevrolet Bolt	EV	Available now
Chevrolet Spark EV	EV	No longer available
Chevrolet Volt	REEV	No longer available
Chrysler Pacifica PHEV	PHEV	Available now
Coda Automotive Coda	EV	No longer available
Fiat 500E	EV	CA only
Fisker Karma	REEV	No longer available
Ford C-MAX Energi	PHEV	No longer available
Ford Focus Electric	EV	No longer available
Ford Fusion Energi	PHEV	Available now
Honda Accord PHEV	PHEV	No longer available
Honda Clarity Full Electric	EV	Available now
Honda Clarity PHEV	PHEV	Available now
Honda Fit EV	EV	No longer available

Make/Model	Fuel Type	Availability
Hyundai Ioniq Electric	EV	CA, CT, ME, MD, MA, NJ, NY, OR, RI, VT only
Hyundai Ioniq PHEV	PHEV	CA, CT, ME, MD, MA, NJ, NY, OR, RI, VT only
Hyundai Kona	EV	CA, CT, ME, MD, MA, NJ, NY, OR, RI, VT only
Hyundai Sonata Plug-In Hybrid	PHEV	CA, CT, ME, MD, MA, NJ, NY, OR, RI, VT only
Jaguar I-Pace	EV	Available now
Karma Revero	PHEV	Available now
Kia Niro EV	EV	Available now
Kia Niro PHEV	PHEV	Available now
Kia Optima PHEV	PHEV	Available now
Kia Soul EV	EV	Available now
Lincoln Aviator	PHEV	Available in 2020
Lincoln Corsair	PHEV	Available in 2020
McLaren Automotive P1	PHEV	No longer available
Mercedes-Benz B Class E	EV	No longer available
Mercedes-Benz c350e	PHEV	Available in 2020
Mercedes-Benz E350e	PHEV	Available in 2020
Mercedes-Benz EQC 400	EV	Available in 2020
Mercedes-Benz GLC350e	PHEV	Available now
Mercedes-Benz GLE550e	PHEV	No longer available
Mercedes-Benz S550e	PHEV	No longer available
Mercedes-Benz S560e	PHEV	Available now
Mini Cooper SE	EV	Available in 2020
Mini Cooper S E Countryman	PHEV	Available now
Mitsubishi i-MiEV	EV	No longer available
Mitsubishi Outlander PHEV	PHEV	Available now
Nissan Leaf	EV	Available now
Porsche 918 Spyder	PHEV	No longer available
Porsche Cayenne S E-Hybrid	PHEV	Available now
Porsche Panamera E-Hybrid	PHEV	Available now
Porsche Taycan	EV	Available in 2020
Smart Fortwo EV	EV	Available now

Make/Model	Fuel Type	Availability
Subaru Crosstrek PHEV	PHEV	Available now
Tesla Model 3	EV	Available now
Tesla Model S	EV	Available now
Tesla Model X	EV	Available now
Tesla Model Y	EV	Available in 2020
Tesla Roadster	EV	No longer available
Think City	EV	No longer available
Toyota Prius Plug In	PHEV	No longer available
Toyota Prius Prime	PHEV	Available now
Toyota RAV4 EV	EV	No longer available
Toyota Scion iQ EV	EV	No longer available
Volkswagen Golf E	EV	CA, CT, DE, DC, ME, MD, MA, NH, NJ, OR, PA, RI, VT, WA only
Volvo S60 T8	PHEV	Available now
Volvo S90 T8	PHEV	Available now
Volvo V60 T8	PHEV	Available now
Volvo XC60 T8	PHEV	Available now
Volvo XC90 T8	PHEV	Available now

Appendix B. EV Charging Overview

B.1. Types of Electric Vehicle Charger Equipment

There are three primary types of EV charging. Level 1 and Level 2 charging provide alternating current (AC) to the vehicle which converts to direct current (DC) needed to charge the battery. The third type, DC fast charging, provides electricity directly to the vehicle's battery. The charge times vary depending on the type of charger, on-board vehicle charging equipment, the vehicle's battery capacity and type of battery, and how depleted the battery is.

Level 1 (AC) Charging	Level 2 (AC) Charging	DC Fast Charging
• Lower Power AC • 120-volt (V) AC circuit or 20 amperes (A) • 4-6 miles of range per hour of charge • Charger unit cost (single port) range: \$300-\$1,500 • Installation cost: \$0-\$3,000 • Most often used in homes, sometimes used at workplaces	• Mid-High Power AC • 208/240-volt (V) AC circuit or 20-100 amperes (A) • 10-20 miles of range per hour of charge • Charger unit cost range: \$400-\$6,500 • Installation cost: \$600-\$12,700 (~\$3,000 average) • Used in homes, workplaces, and for public charging	• DC Fast Charging • 208/480-volt (V) AC 3-phase or 20-400 amperes (A) • 60-80 miles of range per 20 minutes of charge • Charger unit cost range: \$10,000-\$40,000 • Installation cost: \$4,000-\$51,000 (~\$21,000 average) • Most often used for public charging, along heavy traffic corridors

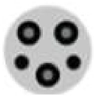
Electric vehicle charging stations, also known as electric vehicle supply equipment (EVSE), consist of the equipment used to deliver electrical energy from an electricity source to an electric vehicle battery. This is done by securely connecting the charger plug to the EV to supply a flow of electricity. The following is a summary of key points and consideration when planning to install an EV charging station.

B.2. Benefits of Hosting an EV Charging Station

- **Customer Attraction and Retention (Corporate Branding):** Offering charging is a direct way to attract and retain EV driving customers.
- **User Charging and Parking Fees:** Charging-station hosts can generate revenue directly from people who use their services. There are various ways to collect revenue for charging such as subscription-based, pay-per-charge, and pay-for-parking systems.
- **Contribution to LEED Certification:** Installing a charging station contributes toward attaining LEED (Leadership in Energy and Environmental Design) certification.
- **Value of Avoided Carbon Emissions:** With a growing number of local and regional carbon-reduction policies, charging station owners may be able to benefit from the value of carbon emissions offset by their stations.
- **Increased Energy Security:** Many station owners have an interest in promoting the energy-security benefits of EV's by making charging stations available.

B.3. Types of Connectors/Plugs

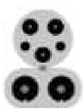
B.3.1. Levels 1 and 2 Charging



SAE J1772: Any vehicle with this plug receptacle can use any Level 1 or Level 2 charger. All major vehicle and charging system manufacturers support this standard, so your vehicle should be compatible with nearly all non-fast charging workplace and public chargers.

B.3.2. DC Fast Charging

CHAdeMO: This is the most common DC fast charger plug. EV OEMs that accept CHAdeMO include Honda, Mitsubishi, and Nissan.



J1772 Combo (CCS): Can use the same charge port when charging with Level 1, 2, or DC Fast Charging. The CCS plug includes 2 additional DC pins below the standard J1772 plug. EV OEMs that accept CCS include Jaguar, Volkswagen Group, General Motors, BMW, Daimler, Ford, FCA, Kia and Hyundai.

Tesla combo: This is a unique charge port for Tesla vehicles

Table 15 shows the approximate % of the electric vehicle's battery that will be charged per hour based on the level of charging (Level 2 or DC Fast) and the size of the battery (25, 50, or 100 kWh).

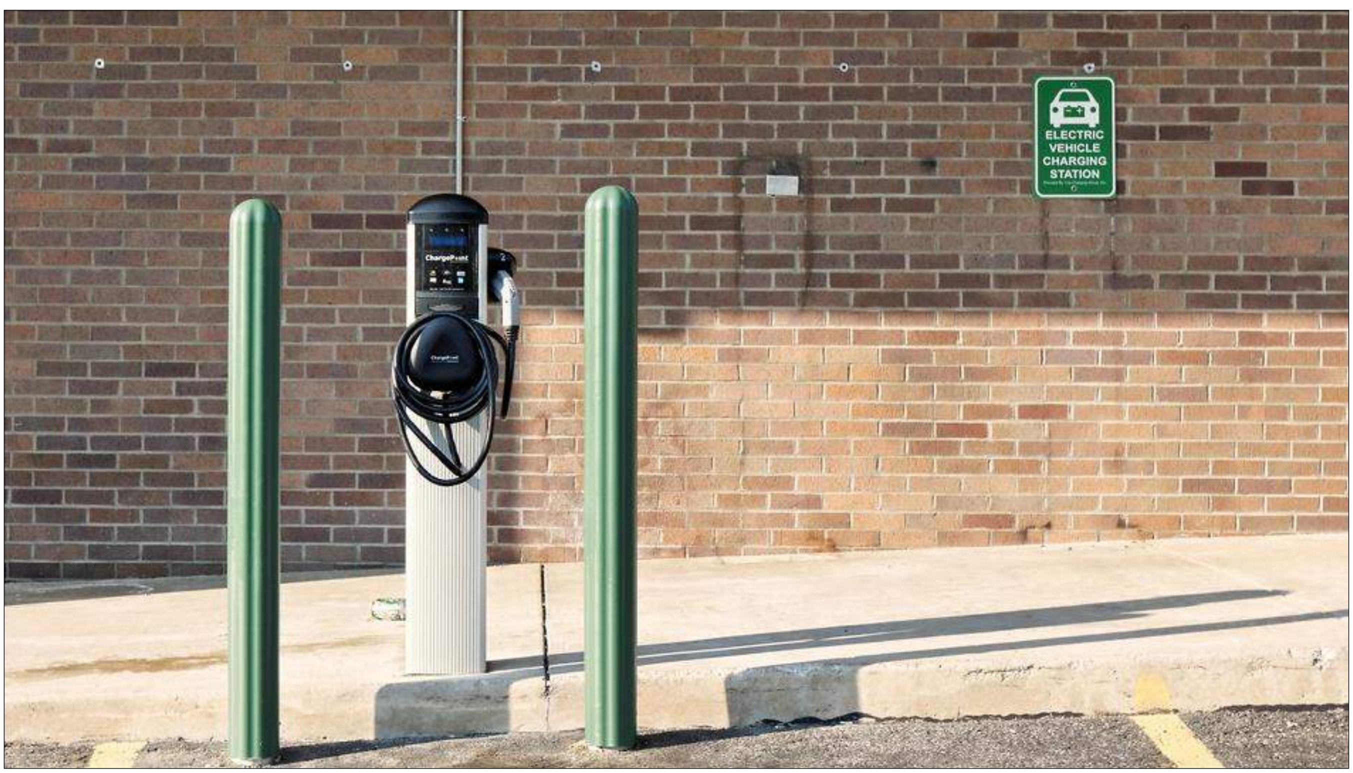
Table 15: Electric Vehicle Charging Station Charge Time Per Hour by Type*

Level 2 (6.5 kW) Charging when Battery is at ...									
... 0%	Battery Size	1 Hour % Charged	2 Hours % Charged	3 Hours % Charged	4 Hours % Charged	5 Hours % Charged	6 Hours % Charged	7 Hours % Charged	8 Hours % Charged
	100 kWh	7%	13%	20%	26%	33%	39%	46%	52%
	50 kWh	13%	26%	39%	52%	65%	78%	91%	100%
	25 kWh	26%	52%	78%	100%				
... 50%	Battery Size	1 Hour % Charged	2 Hours % Charged	3 Hours % Charged	4 Hours % Charged	5 Hours % Charged	6 Hours % Charged	7 Hours % Charged	
	100 kWh	57%	63%	70%	76%	83%	89%	96%	
	50 kWh	63%	76%	89%	100%				
	25 kWh	76%	100%						
DC Fast (50 kW) Charging when Battery is at ...									
... 0%	Battery Size	0.5 Hour % Charged	1 Hour % Charged	1.5 Hours % Charged	2 Hours % Charged				
	100 kWh	25%	50%	75%	100%				
	50 kWh	50%	100%						
	25 kWh	100%							

* Estimates only. Charging for DC fast chargers is not linear.

Figure 17: DCFC at Easton Town Center, Columbus, OH

Figure 18: Level 2 Charger at Walgreens, Akron, OH



B.4. Costs Associated with Charger Installation and Operation

- Charging Level and Amperage Rating
- Charging Ports
- Type of Mounting System
- Networked or Non-Networked
- Connecting the Charger to the Electrical Service
- Electricity Consumption Charges

Appendix C. Electric Vehicles Overview

Electric vehicles, also known as EV's, are powered by electricity, an alternative fuel. Electricity is a scalable, domestic source of energy that is low and stable in price and produced from both non-renewable (e.g., coal, natural gas) and renewable sources (e.g., solar, wind). Electric-drive vehicles use electricity as their primary fuel or to improve the efficiency of conventional vehicle designs by using a battery pack charged by an electric power source to then power an electric motor – all while producing less/no direct tailpipe emissions. Overall, electric vehicles can help increase energy security, improve fuel economy, lower fuel costs, and reduce emissions.

C.1. Electric Vehicle Options and Availability

C.1.1. Two Types

There are two types of vehicles that use electricity either as their primary fuel or to improve the efficiency of conventional vehicle designs:

- **Plug-In Hybrid Electric Vehicles (PHEV):** These vehicles are powered by an internal combustion engine (ICE) and an electric motor that uses energy stored in a battery. They can be plugged into an electric power source to charge the battery but can also be charged by the ICE and through regenerative braking. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline.
- **Battery-Electric Vehicles (BEV):** Also known as all-electric vehicles, these vehicles run on electricity alone. They use a battery to store the electric energy that powers one or more electric motors. EV batteries are charged by plugging the vehicle in to an electric power source and through regenerative braking. These are categorized as zero-emission vehicles because they produce no direct exhaust or emissions.

Availability

Light-, medium-, and heavy-duty electric vehicles are available from a variety of automakers. Although EVs are typically more expensive than conventional and hybrid vehicles, the cost can be recovered through fuel savings or federal tax credit/state incentives.

Driving Range

EV's have a shorter range than comparable conventional gas vehicles, but the efficiency and driving range of EV's vary substantially based on driving conditions (i.e., range can be reduced if more energy is used to heat/cool the cabin due to extreme outside temperatures.

C.2. Electric Vehicle Benefits

In 2019, 59 light-duty PHEV and BEV models were available from major auto manufacturers, according to www.fueleconomy.gov. Electric vehicles are generally more expensive than their conventional counterparts, but lower fuel and maintenance costs make them a competitive option.

C.2.1. Fuel Economy

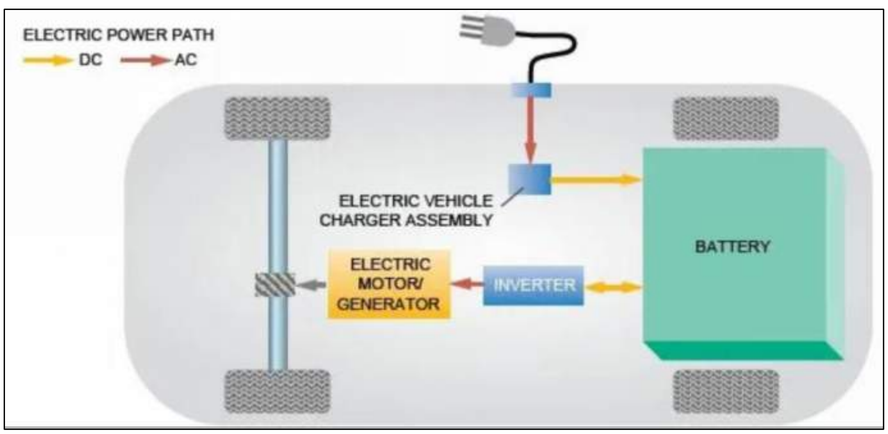
- **PHEVs:** Most achieve combined fuel economy ratings higher than 90 mpge, better than similar hybrids and conventional vehicles (e.g., 2018 Ford Fusion Energi PHEV has 97 mpge).
- **BEVs:** Most achieve combined fuel economy ratings higher than 100 mpge, better than similar hybrids and conventional vehicles (e.g., 2019 Chevrolet Bolt has 119 mpge).

C.2.2. Emissions Reductions

- **PHEVs:** Produce no tailpipe emissions when in electric-only mode and lower emissions than hybrid and similar conventional vehicles when in gasoline mode; life cycle emissions depend on the sources of electricity, which vary based on region.
- **BEVs:** Produce no tailpipe emissions and life cycle emissions depend on the sources of electricity, which vary based on region.

C.2.3. Fuel Cost Savings

- **PHEVs:** When in electric-only mode, PHEV electricity costs about 2 to 4 cents per mile and when in gasoline-only mode, fuel costs range about 5 to 10 cents per mile.



- **BEVs:** Electricity costs 2 to 4 cents per mile for a typical BEV; costs range about 10 to 15 cents per mile for conventional gasoline sedans

C.2.4. Fueling Flexibility

- **PHEVs**: Can fuel at gas stations, can charge at home, public charging stations, and some workplaces
- **BEVs:** Can charge at home, public charging stations, and some workplaces.

Maintenance needs and safety requirements for PHEVs are similar to those of conventional vehicles while BEVs require less maintenance. PHEVs require the same general maintenance as conventional vehicles, but EVs require less maintenance because they have fewer moving parts and fluids to change. Manufacturers are designing these vehicles with maintenance and safety in mind.

C.3. Vehicle Maintenance and Safety

C.3.1. Maintenance Comparison

Because PHEVs have internal combustion engines, maintenance requirements are similar to those of conventional vehicles. The electrical system (battery, motor, and associated electronics) typically requires minimal scheduled maintenance, and brake systems generally last longer because of regenerative braking.

C.3.2. Battery Maintenance

The batteries in electric-drive vehicles are generally designed to last for the expected lifetime of the vehicle. Like the engines in conventional vehicles, the advanced batteries in PEVs are designed for extended life but will wear out eventually. While comprehensive data on PEV battery failures is not available, several manufacturers offer 8-year/100,000-mile warranties for their EV and PHEV batteries.

C.3.3. Safety Requirements

Commercially available electric-drive vehicles must meet the Federal Motor Vehicle Safety Standards and undergo the same rigorous safety testing as conventional vehicles sold in the United States. The exception is neighborhood electric vehicles, which are subject to less-stringent standards because they are typically limited to low-speed roadways as specified by state and local regulations.

C.3.4. Emergency Response and Training

Electric-drive vehicles are designed with cutoff switches to isolate the battery and disable the electric system, and all high-voltage power lines are clearly designated with orange coloring. Manufacturers publish emergency response guides for their vehicles and offer training for emergency responders. The National Fire Protection Association has training and information resources available at evsafetytraining.org.

Appendix D. Data Sources Collected

Source	Data Set	Data Format	Year
AFDC	Existing EV Charging Infrastructure	-	2020
Census	Fairgrounds, state and county	CSV	2015
Census	Colleges and Universities	CSV	2015
Census	Amusement Parks	Layer/Shapefile	2019
ESRI	Sports Venues	Layer	2019
ESRI	Zoos	Layer	2019
ESRI	Malls and Major Shopping Centers	Layer	2019
ODNR	State Parks	Shapefile	2018
ODPS BMV	Ohio Vehicle Registration by location	-	2019
ODOT TIMS	Rest Areas	Shapefile	2017
ODOT TIMS	ODOT Facilities	Shapefile	2017
ODOT TIMS	Outpost (ODOT) Garages	Shapefile	2017
ODOT TIMS	Weight Stations	Shapefile	2017
ODOT TIMS	Traffic Monitoring Data: AADT	Shapefile	2018
ODOT TIMS	Road Inventory	Shapefile	2018
ODOT TIMS	Airports, Public and Private	Shapefile	2017
ODOT TIMS	Public Transportation Facilities	Shapefile	2017
ODOT TIMS	Park and Rides	Shapefile	2017
ODOT TIMS	Ferry Terminals and Ports	Shapefile	2017
ODOT TIMS	Highway Patrol Outpost	Shapefile	2017
OGRIP	State and Local Government Buildings	Shapefile	2018
OTIC	Ohio Turnpike, Service Plazas	CSV	2018
PlugShare	Existing EV Charging Infrastructure	-	2019
PUCO	Electricity map	Shapefile	2018
StreetLight Data	-	-	2020

Source	Data Set	Data Format	Year
USDOT	Truck Stops/Gas Stations	Shapefile	2017
ESRI	Major Hospitals	Shapefile	2010
NPS	National forest	Shapefile	2015
Census	Population	Shapefile	2010
Census	Urban areas (cities and towns)	Shapefile	2013

Appendix E. Existing Direct Current Fast Chargers Within 1 Mile of Corridors

Table 16: Existing DCFC: Interstates

Location	City	No. of Chargers	Network	Charger Type
Akron Metro RTA	Akron	1	ChargePoint Network	CHADEMO J1772COMBO
Walmart	Avon	1	eVgo Network	CHADEMO J1772COMBO
Mickey Mart	Bellville	2	ChargePoint Network	CHADEMO J1772COMBO
City of Bexley - City Hall	Bexley	1	Non-Networked	CHADEMO J1772COMBO
Bob Sumerel Tire and Service	Blue Ash	1	eVgo Network	CHADEMO J1772COMBO
Walmart	Cambridge	4	Electrify America	CHADEMO J1772COMBO
AAA	Cincinnati	1	eVgo Network	CHADEMO J1772COMBO
Harpers Station	Cincinnati	10	Electrify America	CHADEMO J1772COMBO
University of Cincinnati	Cincinnati	1	Non-Networked	CHADEMO J1772COMBO
Walmart	Cincinnati	1	eVgo Network	CHADEMO J1772COMBO
Transformer Station Contemporary Art Space	Cleveland	1	eVgo Network	CHADEMO J1772COMBO
AAA	Columbus	1	eVgo Network	CHADEMO J1772COMBO
Harley-Davidson	Columbus	1	ChargePoint Network	J1772COMBO
City of Upper Arlington	Columbus	2	ChargePoint Network	CHADEMO J1772COMBO
Easton (3 separate locations)	Columbus	6	ChargePoint Network	CHADEMO J1772COMBO
Fulton On-Street	Columbus	2	GreenSpot	CHADEMO J1772COMBO
Nationwide Children's Hospital (3 locations)	Columbus	4	ChargePoint Network	CHADEMO J1772COMBO
Sam's Club	Columbus	1	eVgo Network	CHADEMO J1772COMBO
Walmart	Columbus	8	Electrify America	CHADEMO J1772COMBO
AEP	Gahanna	1	ChargePoint Network	CHADEMO J1772COMBO
Blue Heron Service Plaza	Genoa	4	Electrify America	CHADEMO J1772COMBO
Wyandot Service Plaza	Genoa	4	Electrify America	CHADEMO J1772COMBO
Sheetz	Girard	4	Electrify America	CHADEMO J1772COMBO
Walmart	Huber Heights	6	Electrify America	CHADEMO J1772COMBO

Serpentini Arena	Lakewood	1	ChargePoint Network	CHADEMO J1772COMBO
Walmart	Mansfield	4	Electrify America	CHADEMO J1772COMBO
Walmart	Mason	1	eVgo Network	CHADEMO J1772COMBO
Harley-Davidson	Medina	1	ChargePoint Network	J1772COMBO
Walmart	Milford	1	eVgo Network	CHADEMO J1772COMBO
Mega Lot	North Canton	1	ChargePoint Network	CHADEMO J1772COMBO
Sheffield Crossing Station	Sheffield	4	Electrify America	CHADEMO J1772COMBO
Walmart	Streetsboro	1	eVgo Network	CHADEMO J1772COMBO
Walmart	Strongsville	1	eVgo Network	CHADEMO J1772COMBO
Harley-Davidson	Sunbury	1	ChargePoint Network	J1772COMBO
Walmart	West Chester	1	eVgo Network	CHADEMO J1772COMBO
Indian Meadow Service Plaza	West Unity	4	Electrify America	CHADEMO J1772COMBO
Tiffin River Service Plaza	West Unity	4	Electrify America	CHADEMO J1772COMBO
Worthington Community Center	Worthington	1	ChargePoint Network	CHADEMO J1772COMBO
John McIntire Library	Zanesville	2	ChargePoint Network	CHADEMO J1772COMBO

Table 17: Existing DCFC: U.S. Highway or State Routes

Location	City	No. of Chargers	Network	Charger Type
Athens City Pool	Athens	1	ChargePoint Network	CHADEMO J1772COMBO
Walmart	Aurora	1	eVgo Network	CHADEMO J1772COMBO
Dunkin' Donuts	Broadview Heights	1	eVgo Network	CHADEMO J1772COMBO
AAA	Cincinnati	1	eVgo Network	CHADEMO J1772COMBO
AAA Car Care Plus (2 separate locations)	Columbus	2	eVgo Network	CHADEMO J1772COMBO
Marble Cliff	Columbus	2	ChargePoint Network	CHADEMO J1772COMBO
AAA Car Care Plus	Dublin	1	eVgo Network	CHADEMO J1772COMBO
Walmart	Elyria	1	eVgo Network	CHADEMO J1772COMBO
City of Grove City - Public Parking	Grove City	1	Non-Networked	CHADEMO J1772COMBO
City of Lancaster	Lancaster	1	ChargePoint Network	CHADEMO J1772COMBO
Sheetz	Mentor	4	Electrify America	CHADEMO J1772COMBO
Harley Davidson	Mentor	1	ChargePoint Network	J1772COMBO
Doubletree Hotel	Newark	2	ChargePoint Network	CHADEMO J1772COMBO

Walmart	Stow	1	eVgo Network	CHADEMO J1772COMBO
City of Wooster	Wooster	2	ChargePoint Network	CHADEMO J1772COMBO
Old Worthington	Worthington	1	ChargePoint Network	CHADEMO J1772COMBO

Appendix F. Annual Average Daily Traffic for Ohio U.S. Highways and State Routes

Figure 19: U.S. and State Routes with 5,000+ AADT

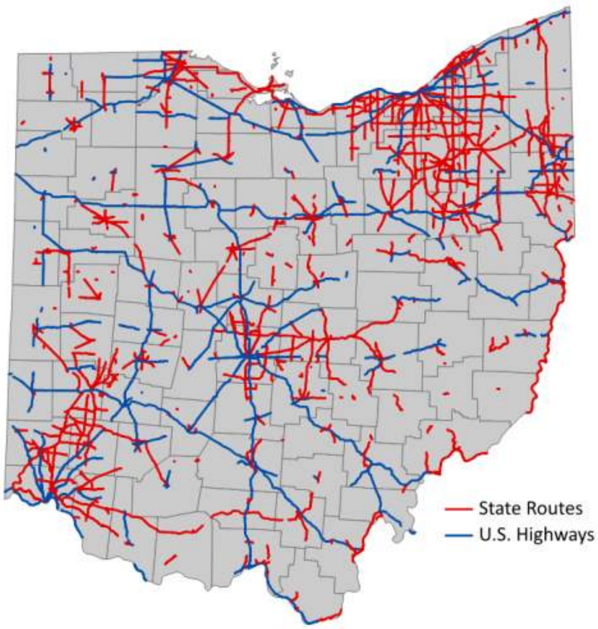


Figure 21: U.S. and State Routes with 10,000+ AADT

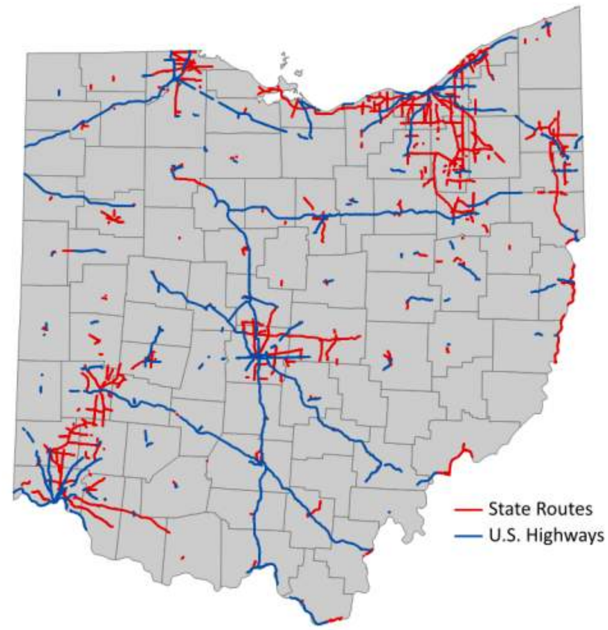


Figure 20: U.S. and State Routes with 15,000+ AADT

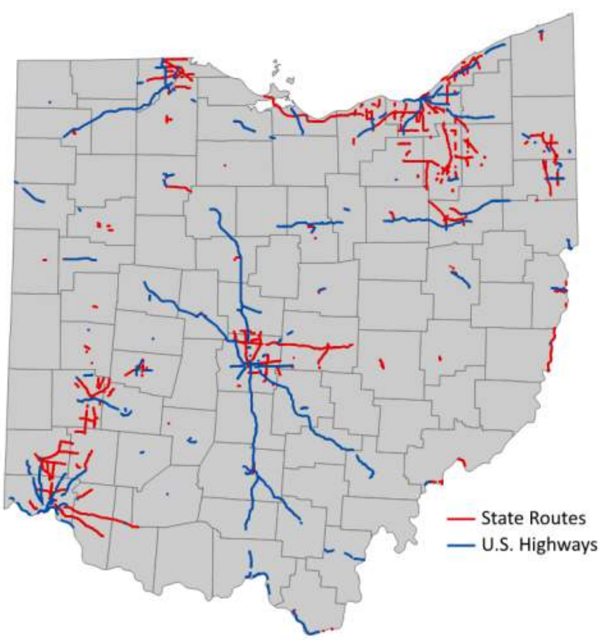
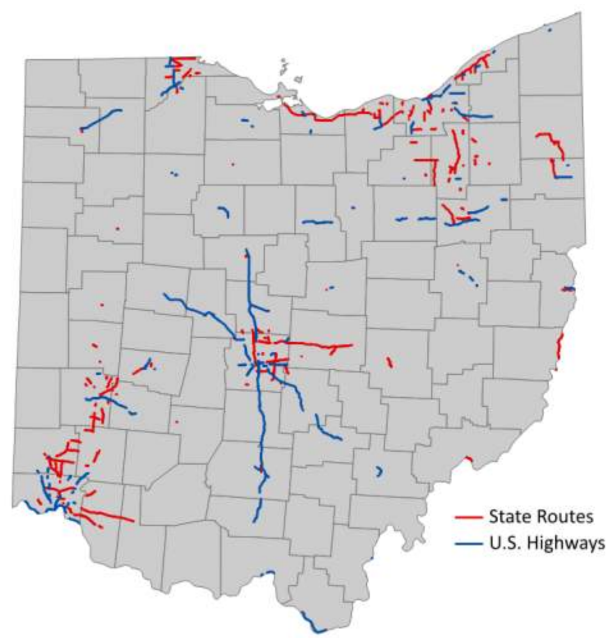


Figure 22: U.S. and State Routes with 20,000+ AADT



Appendix G. Level 2 Recommendations Summary

Table 18: Methodology for Ranking Top Ohio Tourist Attractions by Website Recommendation

Legend:		**Recommended Attraction for Level 2 Charging**

	Attraction Listed on Website											
Attraction	**Cleveland.com**	**Trip Advisor**	**Vacation Idea**	**The Crazy Tourist**	**Ohio Traveler**	**Google Trips**	**Ohio Tourism**	**Top Ohio Parks**	**No.**	**Existing Charging?**	**Ports**	**Notes**
Cedar Point Amusement Park	1	1	1	1	1	1	1		7	No		
Hocking Hills State Park*	1	1		1	1	1	1	1	7	Yes	1	Located at Inn & Spa at Cedar Falls, add at Visitor Parking Lot
Rock and Roll Hall of Fame	1	1	1	1		1	1		6	Yes	2	Downtown City of Cleveland - Charging at Science Center
National Museum – U.S. Air Force	1	1	1		1	1			5	Yes	2	
West Side Market		1	1	1	1	1			5	No		City of Cleveland - Short term parking not conducive to Level 2
American Sign Museum		1	1	1	1				4	No		City of Cincinnati
Cincinnati Contemporary Arts Center			1	1	1	1			4	Yes	2	
Cincinnati Underground Railroad Freedom Center**		1		1	1	1			4	No		City of Cincinnati
Cincinnati Zoological Gardens		1	1	1		1			4	Yes	8	
Cleveland Zoo		1	1	1		1			4	No		City of Cleveland
Cleveland Museum of Art		1	1	1		1			4	No		University Circle
Franklin Park Conservatory and Botanical Gardens		1	1	1		1			4	No		City of Columbus

Legend:		Recommended Attraction for Level 2 Charging

Attraction Listed on Website

Attraction	Cleveland.com	Trip Advisor	Vacation Idea	The Crazy Tourist	Ohio Traveler	Google Trips	Ohio Tourism	Top Ohio Parks	No.	Existing Charging?	Ports	Notes
Kings Island	1	1	1			1			4	No		
Pro Football Hall of Fame	1	1			1		1		4	No		City of Canton
Stan Hywet Hall & Gardens		1	1	1	1				4	No		City of Akron
Columbus Zoo and Aquarium	1			1		1			3	Yes	3	
COSI			1		1	1			3	Yes	6	
Mohican State Park Lodge*	1					1		1	3	Yes		Located in Campground, add at Visitor Parking Lot
Toledo Museum of Arts		1	1		1				3	Yes	2	
Toledo Zoo		1			1	1			3	No		City of Toledo
African Safari Wildlife Park					1	1			2	No		
Cincinnati Art Museum		1	1						2	No		
Cincinnati Union Terminal				1	1				2	No		
Jungle Jim's International Market			1		1				2	No		Level 1 charging available
Perry's Victory Intl Peace Memorial			1			1			2	No		Put-In-Bay Island
Playhouse Square			1	1					2	No		
Salt Fork State Park Lodge*	1							1	2	No		
The Wilds			1		1				2	No		

** Also included as an ODNR priority location*

*** Includes area where Paul Brown Stadium and the Great American Ballpark are located*

Table 19: Recommended Level 2 Charger Location Summary

Potential Location	VW Funding Availability	Utility	ODOT District	County	MPO
Ohio Attractions					
Cedar Point	x	Ohio Edison	3	Erie	ERPC
Kings Island	x	Duke Energy	8	Warren	OKI
National Underground Railroad Freedom Center	x	Duke Energy	8	Hamilton	OKI
Cleveland Zoo	x	First Energy	12	Cuyahoga	NOACA
Cleveland Museum of Art	x	First Energy	12	Cuyahoga	NOACA
Pro Football Hall of Fame	x	AEP	4	Stark	SCATS
Toledo Zoo	x	Toledo Edison	2	Lucas	TMACOG
Cincinnati Union Terminal	x	Duke Energy	8	Hamilton	OKI
ODNR State Parks and Lodges					
Mohican State Park Lodge		Licking Rural	3	Ashland	N/A
Salt Fork State Park Lodge		Guernsey-Muskingum	5	Guernsey	N/A
Maumee Bay State Park Lodge*	x	Toledo Edison	2	Lucas	TMACOG
Punderson State Park Lodge*	x	First Energy	12	Geauga	NOACA
Burr Oak State Park Lodge *		AEP	10	Morgan	N/A
Deer Creek State Park Lodge*		South Central Power/Dayton Power & Light	6	Pickaway	N/A
Hueston Woods State Park Lodge*	x	Butler Rural Electric	8	Preble	N/A
Shawnee State Park Lodge *		AEP	9	Scioto	N/A
Marblehead Lighthouse State Park*	x	Ohio Edison	2	Ottawa	TMACOG
Hocking Hills State Park		South Central Power	10	Hocking	N/A
Caesar Creek State Park*	x	Dayton Power & Light	8	Warren	OKI
ODOT District Offices					
ODOT District 1 HQ		AEP	1	Allen	LACRPC
ODOT District 2 HQ		Toledo Edison	2	Wood	TMACOG
ODOT District 3 HQ		Ohio Edison	3	Ashland	N/A
ODOT District 4 HQ	x	Ohio Edison	4	Summit	AMATS
ODOT District 5 HQ	x	AEP	5	Licking	LCATS
ODOT District 6 HQ	x	AEP	6	Delaware	MORPC

Potential Location	VW Funding Availability	Utility	ODOT District	County	MPO
ODOT District 7 HQ		Dayton Power & Light	7	Shelby	N/A
ODOT District 8 HQ	x	Duke Energy	8	Warren	OKI
ODOT District 9 HQ		AEP	9	Ross	N/A
ODOT District 10 HQ		AEP	10	Washington	WWWIPC
ODOT District 11 HQ		AEP	11	Tuscarawas	N/A
ODOT District 12 HQ	x	First Energy	12	Cuyahoga	NOACA
ODOT Central Office	x	AEP	6	Franklin	MORPC
ODPS Facilities					
ODPS Headquarters	x	AEP	6	Franklin	MORPC
ODPS EMA Building	x	AEP	6	Franklin	MORPC
ODPS Alum Creek Facility	x	AEP	6	Franklin	MORPC
Ohio Turnpike and Infrastructure Commission Headquarters	x	First Energy	12	Cuyahoga	NOACA

** ODNR Preferred Location*

Appendix H. State Park Zone Activity Analysis

To get a better understanding of the drivers going to the recommended Level 2 charging locations at state parks, an extended analysis using StreetLight Data was conducted. StreetLight Data is a transportation analytics company that uses the processing of big data (smartphones or navigation devices) to answer mobility and transportation questions. The company's online platform allows users to analyze various transportation metrics by zone.

The state parks studied include the eight state park lodges and three other popular state parks without lodges. The analysis looked at the amount of traffic ending their trips at the visitor parking locations and surrounding areas of each state park in 2019. Weekends during the months of June, July, and August were analyzed in order to decrease any favorable bias due to geographical locations of each state park, and to coincide with the peak tourism season during the summer vacation months.

Figure 23 shows the total zone traffic volume that each of the state parks experienced under the conditions described above. Hocking Hills State Park, a top attraction based on the Ohio Tourism website, shows the most number of 2019 summer weekend destination trips with an average of 1,213.

Figure 23: Ohio State Park Zone Weekend Traffic Destination Volumes, June – August 2019

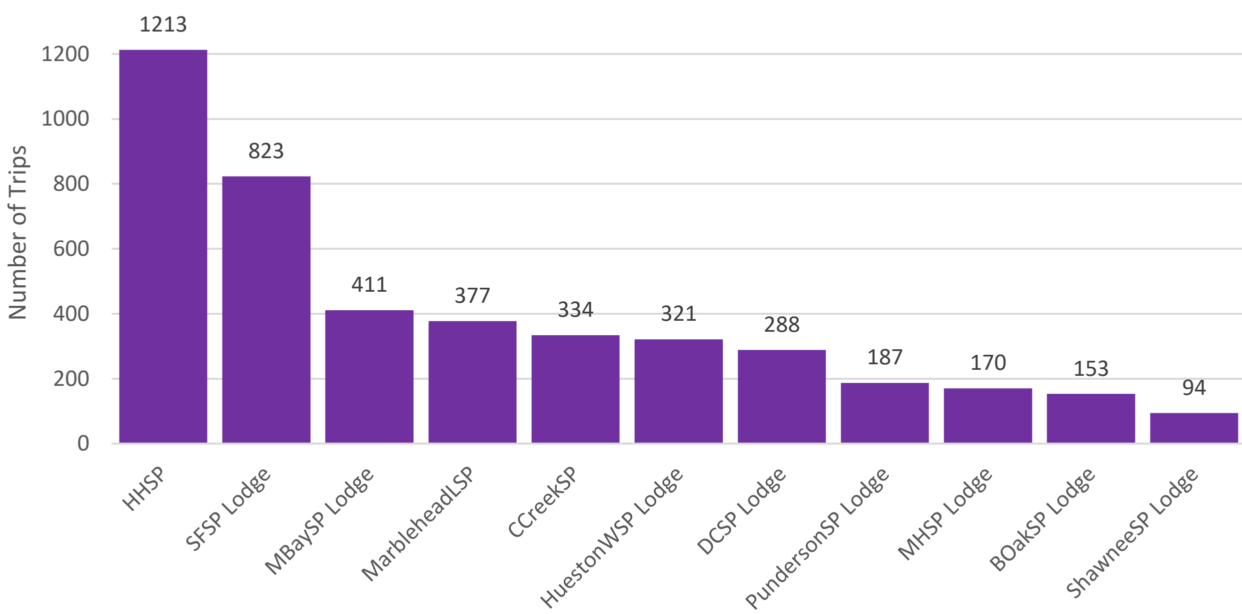


Figure 24 and **Figure 25** show a breakdown of the StreetLight Data analysis. Attributes include the total number of trips by either length of trip or trip duration that drivers took to get to the state parks. Sixty-five percent (65%) of the trips were shown to be under 20 miles. However, this platform interprets a trip to have ended if the vehicle hasn't moved more than 5 meters in 5 minutes. If these criteria are met, the trip is considered as terminated and will restart when the vehicle begins to move again. Because of this limitation, trips may be artificially short if people stop for gas or other amenities en route to their final destination. A more thorough analysis using this type of data could help estimate site-specific metrics such as average battery depletion levels for EVs drivers once they arrive at the destination.

Figure 24: Ohio State Park Zone Weekend Traffic Destination Trip Duration, June – August 2019

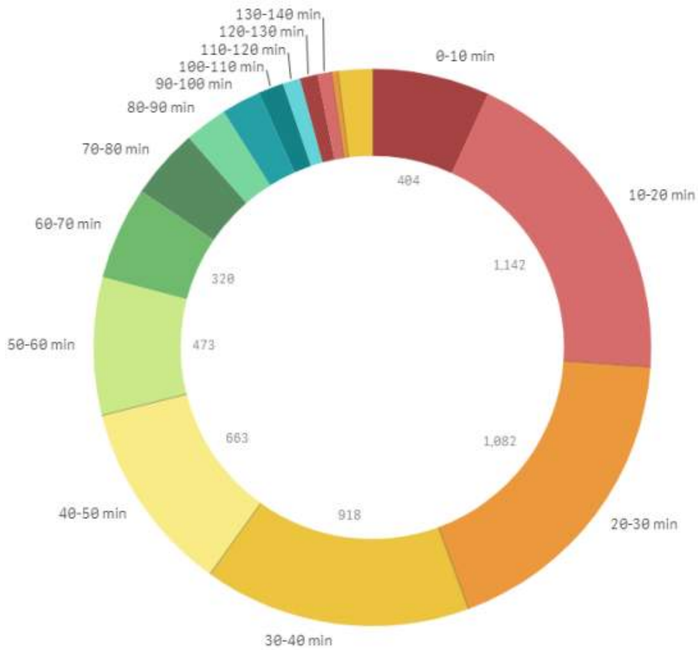
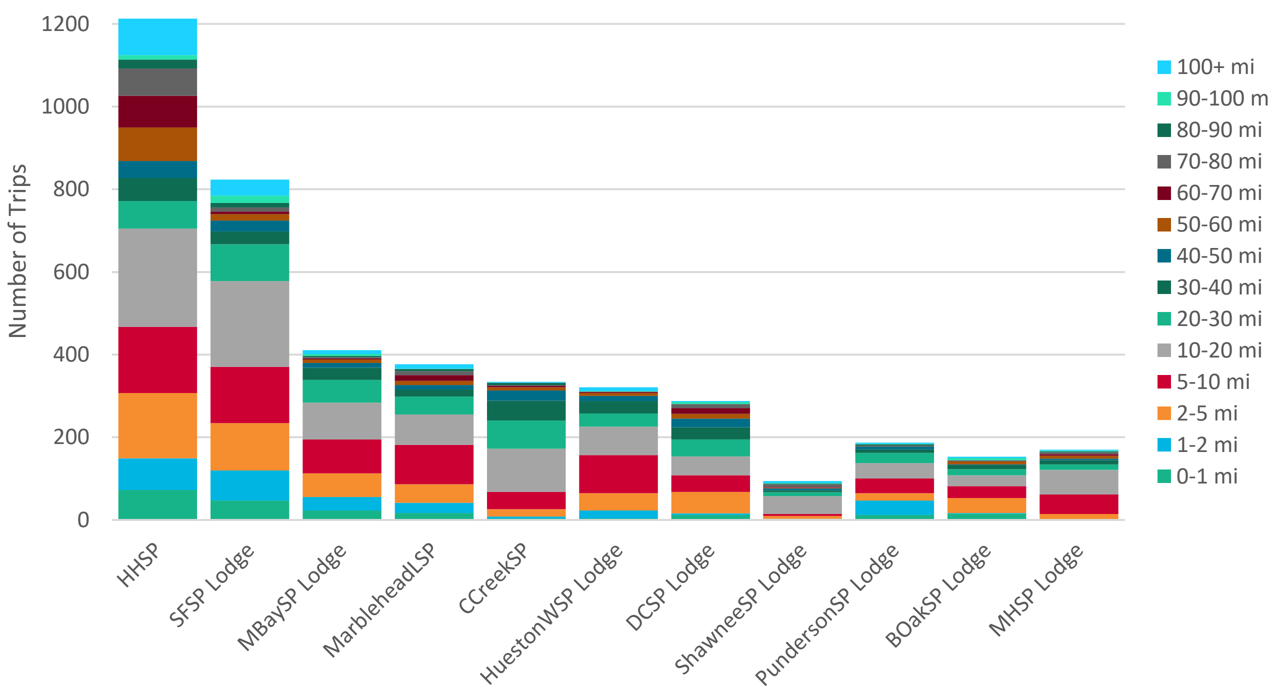


Figure 25: Ohio State Park Zone Weekend Traffic Destination Trip Length, June – August 2019



Appendix I. Charging Infrastructure Incentives

I.1. Electrify America (EA)

EA is a private company created through the settlement with Volkswagen (VW) for violations of the federal Clean Air Act. $2 billion of settlement funds were set aside for fast EV charging, $800 million in California and the remaining $1.2 billion throughout the rest of the country. EA already has developed a handful of sites along Ohio Interstates with more expected in two subsequent funding rounds over the next few years.

I.2. Smart Columbus

The privately funded portion of Smart Columbus has included a small rebate program aimed at MUD sites. Several Columbus area companies also developed workplace charging as part of pledges made under Smart Columbus. None of the funding has been used for DCFC.

I.3. AEP Ohio

In April 2018, the PUCO approved a program proposed by AEP Ohio to provide $10 million in rebates for EV charging. The utility's program, launched in August 2018, includes fast charging, MUD and workplace sites within AEP's Ohio territory. As of October 18, 2019, AEP has approved and activated 11 DCFC stations and has 49 additional applications for 80 stations in process. Most of these will be within Central Ohio and a few are expected in other portions of their territory.

I.4. Ohio EPA Diesel Mitigation Trust Fund

The Ohio EPA's Diesel Mitigation Trust Fund (DMTF) was created from another portion of the VW settlement that provides funding to each state based on a formula. Terms of the settlement allow states to allocate 15% of these funds to zero-emission refueling or recharging facilities. The other portion of Ohio's DMTF is dedicated to grants for replacements of old diesel vehicles. Ohio received a total of $75 million in total formula funding and has allocated 15% to EV charging incentives. Program rules will direct all funding to 26 eligible counties located primarily in Southwest, Central and Northeast Ohio. Ohio EPA is expected to issue its first solicitation for these funds in 2020 and is planned to fund Level 2 stations. The second solicitation is expected later in the year for DCFC.

I.5. Northern Ohio Area Coordinating Agency

Northern Ohio Area Coordinating Agency (NOACA) is developing an EV charger incentive program that covers their five-county territory in Northeast Ohio. Details are pending.

I.6. Additional Sources

Because EV charging stations that are accessible to the public are eligible under the CMAQ program, regional planning agencies could prioritize spending for new facilities, either owned by governments or possibly private sites through public/private partnerships. In addition to investor-owned utilities, Ohio's municipal and cooperative utilities may decide to develop funding programs or develop individual projects based on targeted needs. Local governments themselves also may decide to provide some support.

DriveOhio anticipates the following additional sources for EV charging.

I.6.1. Duke Energy

In September, Duke Energy included a proposal for a $15 million pilot program also included in a larger grid modernization filing. It would cover Duke Energy's operating territory in Southwest Ohio. The proposed program would include DCFC as well as Level 2 in public, workplace and residential locations. The program might provide for make ready electric infrastructure upgrades for charging, or it might provide funds for charging equipment as well.

I.6.2. First Energy

First Energy (FE) is not currently planning to propose an EV charging program but is studying the issue and may develop a proposal over the next few years.

I.6.3. U.S. Department of Transportation

In 2018, legislation was introduced in the U.S. Senate to provide $300 million in federal funding to help support development of EV charging infrastructure, particularly along highway corridors. Under the proposal, funding would be tied to EV "signage pending" corridors designated as such by the FHWA. The federal FAST Act for surface transportation expires in 2020. When the Act is renewed and if it includes funding for EV corridor charging, Ohio will be well-positioned to receive significant support.

Appendix J. Direct Current Fast Charger Recommendations Summary

Table 20: Interstate Direct Current Fast Charger Recommended Locations

Interstate	Gap No.	Gap Length	Potential Location	VW Funding Availability	Public	Utility	ODOT District	County	MPO	Potential Facility
I-70	1	18.1 mi	Exit 14, Lewisburg			DP&L	8	Preble	N/A	Gas stations, Dollar General
			Between MP 2 and 3, Preble		x	DP&L				Rest Area (Preble)
	2	12.2 mi	Exit 59, Springfield			Ohio Edison	7	Clark	CCSTCC	Love's Travel Stop/BP Gas station
			Between MP 70 and 71, South Vienna		x	Ohio Edison				Rest Area (Madison)
			Exit 66, South Vienna			South Vienna	7	Clark	CCSTCC	Gas stations, restaurants
	3	3.3 mi	Exit 129, Buckeye Lake	x		AEP	5	Licking	LCATS	BP Gas Station/Wendy's
	4	32.6 mi	Exit 208, Belmont			AEP	11	Belmont	Bel-O-Mar	Pilot Travel Center/Exxon/Marathon
			Between MP 210 and 211, Morristown		x	AEP				Rest Area (Belmont)
			Exit 218, St. Clairsville			South Central Power	11	Belmont	Bel-O-Mar	Walmart
I-71	5	8.6 mi	Exit 186, Ashland			Ohio Edison	3	Ashland	N/A	Gas station with Starbucks
	6	20.2 mi	Exit 65, Jeffersonville			DP&L	6	Fayette	N/A	Outlet mall, restaurants
			Between MP 67 and 68, Jeffersonville		x	DP&L				Rest Area (Fayette)

Interstate	Gap No.	Gap Length	Potential Location	VW Funding Availability	Public	Utility	ODOT District	County	MPO	Potential Facility
	7	16.4 mi	Exit 50, Wilmington			DP&L	8	Clinton	N/A	Gas stations, restaurants
I-75	8	15.8 mi	Exit 181, Bowling Green			BG Municipality	2	Wood	TMACOG	Meijer
			Between MP 178 and 179, Portage		x	Hancock Wood Electric	2	Wood	TMACOG	Rest Area (Findlay)
	9	22.2 mi	Exit 167, North Baltimore			AEP	2	Wood	TMACOG	Love's Travel Stop/BP Gas Station
			Exit 159, Findlay			AEP	1	Hancock	N/A	Walmart
			Between MP 152 and 153, Findlay		x	Midwest Electric				Rest Area (Hancock)
	10	39.1 mi	Exit 135, Beaverdam			AEP	1	Allen	LACRPC	Pilot Travel Center/McDonalds
	11	32.3 mi	MP 114, Wapakoneta		x	Midwest Electric	7	Auglaize	N/A	Rest Area (Auglaize) (SB Only)
			Exit 99, Anna			Pioneer Electric	7	Shelby	N/A	Gas stations, restaurants
			Exit 92, Sidney			DP&L	7	Shelby	N/A	Walmart
			Between MP 80 and 81, South Piqua		x	DP&L				Rest Area (Miami)
	12	41.5 mi	Exit 59, Dayton	x		DP&L	7	Montgomery	MVRPC	Walmart
I-76	13	3.2 mi	Exit 38, Rootstown	x		Ohio Edison	4	Portage	AMATS	Giant Eagle
			Between MP 45 and 46, Rootstown		x	Ohio Edison	4	Portage	AMATS	Rest Area (Portage)
	14	23.9 mi	Exit 81, New Philadelphia			AEP	11	Tuscarawas	N/A	Walmart

Interstate	Gap No.	Gap Length	Potential Location	VW Funding Availability	Public	Utility	ODOT District	County	MPO	Potential Facility
			Exit 65, Newcomerstown			AEP	11	Tuscarawas	N/A	Duchess
	15	22.4 mi	Exit 25, Caldwell			AEP	10	Noble	N/A	Pilot Travel Center
			Exit 6, Devola			AEP				Gas Stations
			Between MP 3 and 4, North Marietta		x	Washington Electric				Rest Area, NB Only (Washington)
			Exit 1, Marietta			AEP	10	Washington	WWWIPC	Kroger, Walmart
I-90	16	30.1 mi	Between MP 242 and 243, Conneaut	x	x	FirstEnergy	4	Ashtabula	N/A	Rest Area, WB Only (Ashtabula)
			Exit 223, Austinburg	x		FirstEnergy	4	Ashtabula	N/A	Pilot & Flying J Travel Center
	17	20.0 mi	Exit 193, Kirtland[a]			FirstEnergy				McDonalds/7-Eleven

= Location not suitable due to lack of 3-phase power availability. Not shown on map.

[a] *Electrify America charging stations 1.3 miles away from suggested location. Given that First Energy is nearing capacity at this site and cannot support DCFC, this location was not including in the cost estimates.*

Table 21: U.S./State Route Direct Current Fast Charging Recommended Locations

Route	Gap No.	Potential Location	VW Funding Availability	Utility	Potential Facility	ODOT District	County	MPO
US 23	18	Intersection with Charleston Pike, Chillicothe		AEP	Pilot Travel Center	9	Ross	N/A
US 23	19	Intersection with Wyandot Ave, Upper Sandusky		AEP	Pilot Travel Center	1	Wyandot	N/A
US 23	20	Intersection with SR 95, Marion		Ohio Edison	Walmart/Meijer	6	Marion	N/A

US 33	21	Intersection with US 68, Bellefontaine		DP&L	Marathon	7	Logan	N/A
US 24	22	Intersection with N Clinton St, Defiance		Toledo Edison	Walmart	1	Defiance	N/A
SR 2	23	Intersection with US 250, Sandusky	x	Ohio Edison	Walmart	3	Erie	ERPC
US 23	24	Off US 23, Portsmouth		AEP	Kroger	9	Scioto	N/A

Table 22: Ohio Turnpike Direct Current Fast Charging Recommended Locations*

Route	Potential Location	VW Funding Availability	Utility	County
I-80/I-90	MP 100.0 - Commodore Perry (EB), Erie Islands (WB)	x	Toledo Edison	Sandusky
I-80/I-90	MP 139.5 – Vermilion Valley (EB), Middle Ridge (WB)	x	Ohio Edison (EB), Amherst Municipal Electricity (WB)	Lorain
I-80	MP 170.1 – Towpath (EB), Great Lakes (WB)	x	The Illuminating Company	Cuyahoga
I-80	MP 197.0 – Brady's Leap (EB), Portage (WB)	x	Ohio Edison	Portage
I-80	MP 237.2 – Glacier Hills (EB), Mahoning Valley (WB)	x	Ohio Edison	Mahoning

** Gap numbers were not assigned for the coverage gaps along the Ohio Turnpike due to the differences in analysis methodology (see Section 6.1.1).*

Table 23: Interstate Gap Descriptions

Interstate Gap	Details
Gap 1	Includes one proposed private location off Exit 14 on I-70 close to Lewisburg. Rest area originally proposed does not have any 3-phase power readily available. Dayton Power & Light serves the proposed location.
Gap 2	Includes two proposed private locations at Exit 59 close to Springfield and Exit 66 close to South Vienna on I-70. The locations are served by Ohio Edison and South Vienna Municipal Power, respectively. Rest area originally proposed past South Vienna does not have 3-phase power available.
Gap 3	Only contains one proposed private location just outside gap 3 due to limited amount of exits on the stretch of I-70. Potential site at Exit 129 is served by AEP and has 3-phase power readily available as well as it being eligible for VW funding.

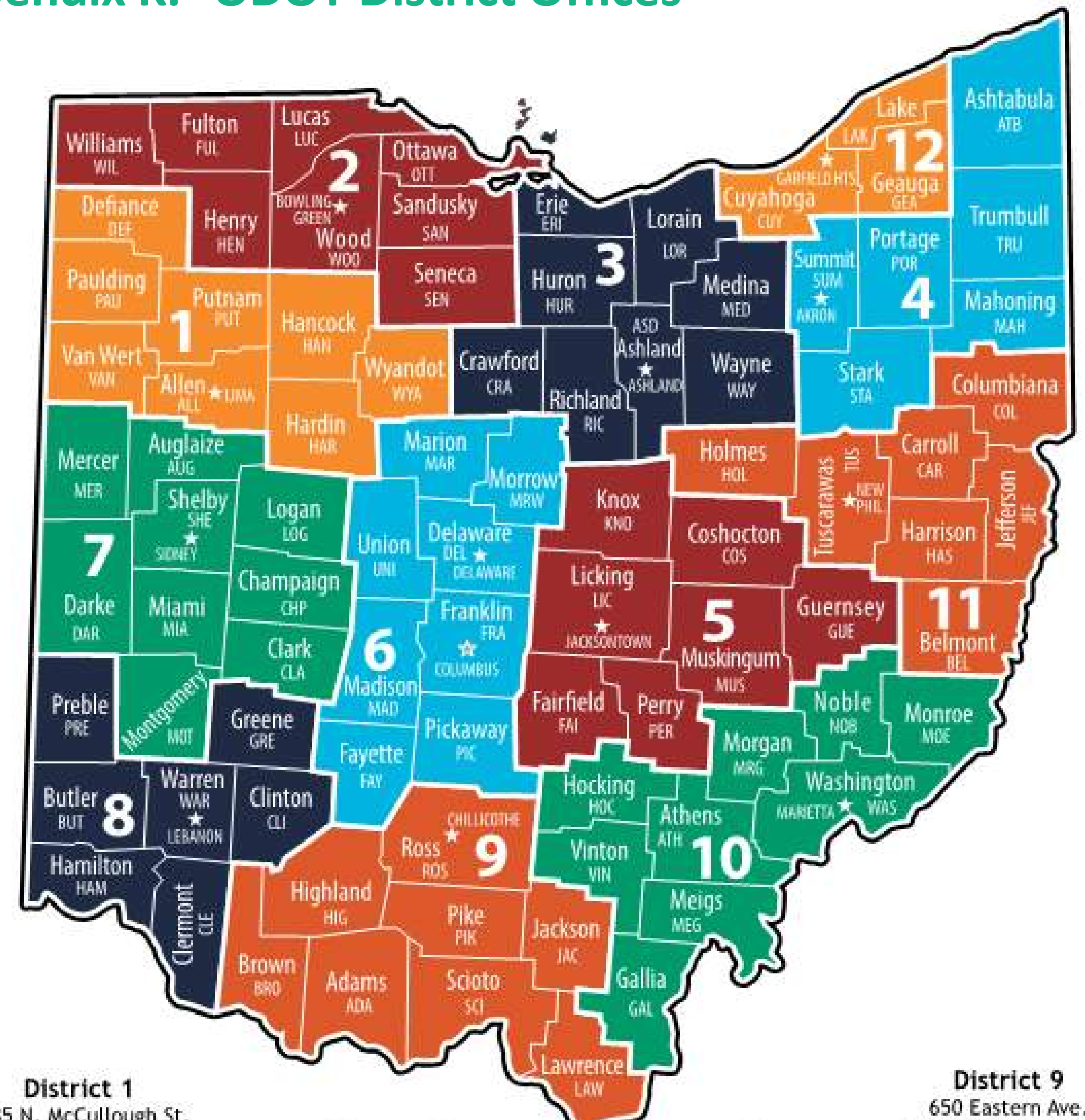
Interstate Gap	Details
Gap 4	Includes two different potential private locations that are about 10 miles apart. One is located close to Belmont and the other to St. Clairsville, both sites have 3-phase power available. Power at Exit 208 is served by AEP. Power at Exit 218 is served by South Central Power. Rest area originally proposed is not included due to lack of 3-phase power.
Gap 5	Due to lack of suitable areas around the gap, the location recommended is just outside of gap 5. However, the proposed private location is just off Exit 186 and includes a variety of amenities as well as 3-phase power readily available.
Gap 6	Includes only one proposed location due to the lack of 3-phase power at the rest area originally proposed. The private location at Exit 65 being recommended is served by Dayton Power & Light and has 3-phase power available.
Gap 7	Includes only one proposed private location due to the limited exits on the gap. The gap is served by Dayton Power & Light. Potential sites are off Exit 50 and have 3-phase power available.
Gap 8	Includes two possible sites, one private site at Exit 181 and one rest area. The rest area could serve both north and southbound of I-75. Area is served by Hancock Wood Electric and Bowling Green Municipal Utilities. Gap was extended due to nearby DCFC only being located at the Ohio Turnpike and would make it difficult for EV drivers to deviate from I-75 to charge their vehicle.
Gap 9	Both recommended private locations are eight miles apart at Exits 159 and 167 that are served by AEP with 3-phase power readily available. A potential rest area in the gap was originally recommended but lack of 3-phase power made it unsuitable for DCFC.
Gap 10	Due to lack of exits along the corridor found in the gap, there is only one proposed private location at Exit 135 near Beaverdam. The potential sites have 3-phase power available and are served by AEP.
Gap 11	One of the longest gaps identified in the network with 3 potential locations identified; 2 private locations (Exits 159 and 167) and 1 rest area. The rest area with available 3-phase power only serves southbound traffic. The gap is served by Dayton Power & Light and Midwest Electric from Ohio's Electric Cooperatives.
Gap 12	Includes one proposed private location at Exit 59 on I-75 near Dayton. Although the recommended location is fairly close to an existing DCFC, it is being suggested to complement the intercity travel on I-75 as EV drivers would have to deviate to I-70 to use the existing DCFC infrastructure. The proposed site has 3-phase power available and it is served by Dayton Power & Light. The proposed site is eligible for VW funds.
Gap 13	Similar to Gap 12, this gap was created to support the intercity travel for EV drivers along I-76. The gap shown, although is covered by existing surrounding DCFC, was created because of the inconvenience for EV drivers having to deviate from I-76 to use existing infrastructure. The one recommended private location at Exit 38 is served by Ohio Edison and 3-phase power is available. The rest area in this gap was not suitable due to lack of 3-phase power. The proposed private location is eligible for VW funds.
Gap 14	Includes two recommended private locations at Exit 65 and Exit 81, where both have 3-phase power available and are served by AEP.

Interstate Gap	Details
Gap 15	Includes two recommended private locations for DCFC at Exit 1 and Exit 25. Due to other possible locations (one being a rest area) not having 3-phase power available, the gap was extended to be longer to include an option by Caldwell. Both possible locations being recommended are served by AEP.
Gap 16	Has two recommended locations including a rest area that only serves westbound traffic. Both locations are eligible for VW funding and are served by First Energy. Note that if the rest area in Ashtabula is selected rather than the potential private sites at Exit 223, the distance between the rest area and the existing Electrify America DCFC in Mentor is just greater than 50 miles apart for westbound traffic, not meeting FHWA EV Signage Ready standards. Since the rest area only serves westbound traffic, the gap between DCFCs in the eastbound direction is even larger. For this reason, it is recommended that the private sites at Exit 223 be prioritized over the rest area in Ashtabula.
Gap 17	Does not have any proposed locations as the only location that was investigated was reaching electric capacity. It is important to note, however, that there is an existing Electrify America DCFC just 1.3 miles away from the I-90 corridor in Mentor that makes up the gap.

Table 24: U.S./State Route Gap Descriptions

U.S./SR Gaps	Details
Gap 18	Includes one possible private location near Chillicothe where 3-phase power is available and served by AEP.
Gap 19	Includes one possible private location near Upper Sandusky where 3-phase power is available and served by AEP.
Gap 20	Includes one possible private location near Marion where 3-phase power is available and served by Ohio Edison.
Gap 21	Includes one possible private location near Bellefontaine where 3-phase power is available and served by Dayton Power and Light.
Gap 22	Includes one possible private location near Defiance where 3-phase power is available and served by Toledo Edison.
Gap 23	Includes one possible private location near Sandusky where 3-phase power is available and served by Ohio Edison. This location is eligible for VW funding.
Gap 24	Includes one possible private location near Portsmouth where 3-phase power is available and served by AEP.

Appendix K. ODOT District Offices



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Lima, OH 45801-0040
419-222-9055

District 2
317 East Poe Rd.
Bowling Green, OH 43402-1330
419-353-8131

District 3
906 Clark Ave.
Ashland, OH 44805-1989
419-281-0513

District 4
2088 S. Arlington Rd.
Akron, OH 44306
330-786-3100

District 5
9600 Jacksontown Rd.
Jacksontown, OH 43030
740-323-4400

District 6
400 East William St.
Delaware, OH 43015
740-833-8000

District 7
1001 St. Marys Ave.
Sidney, OH 45365-0969
937-492-1141

District 8
505 S. State Route 741
Lebanon, OH 45036-9518
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District 9
650 Eastern Ave.
Chillicothe, OH 45601
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338 Muskingum Dr.
Marietta, OH 45750
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District 11
2201 Reiser Ave.
New Philadelphia, OH 44663
330-339-6633

District 12
5500 Transportation Blvd.
Garfield Heights, OH 44125-5396
216-581-2100


EXIT 99A
71 SOUTH
Cincinnati
70 WEST
Dayton
BOLT EV